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EDITORIAL NOTES.

THE Council of the Geological Society has made the following awards:—The Wollaston Medal to Dukinfield Henry Scott, M.A., LL.D., D.Sc., F.R.S., in recognition of the value of his researches in fossil botany. The Murchison Medal to Dr. Jakob Johannes Sederholm, in recognition of his researches in petrology, especially of the granites and gneisses of the Pre-Cambrian Complex of Fennoscandia. A Lyell Medal to Professor Sidney Hugh Reynolds, M.A., Sc.D., in recognition of the value of his researches in the stratigraphy of the Palaeozoic rocks and in vertebrate palaeontology. A second Lyell Medal to William Dickson Lang, M.A., Sc.D., for his researches in stratigraphy and palaeontology, especially with reference to the Bryozoa. The Wollaston Donation Fund to James Wright, for his researches on the Crinoidea of the Carboniferous Limestone of Scotland. The Murchison Geological Fund to George Slater, D.Sc., A.R.C.S., in recognition of the value of his researches in glaciology. The Lyell Geological Fund to Ben Lightfoot, M.C., M.A., for his researches on the economic geology of Southern Rhodesia.

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IN the list of New Year Honours we note with pleasure the conferment of a knighthood on Dr. E. H. Pascoe (St. John's College, Cambridge), Director of the Geological Survey of India.

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THE Fifteenth International Geological Congress will be held in South Africa in 1929. After much consideration the months of July and August have been chosen as most generally convenient. The inaugural session will be at Pretoria between 29th July and 12th August, and there will be excursions both before and after these dates. According to custom certain subjects have been chosen as specially appropriate for discussion in South Africa: those provisionally fixed are as follows: the differentiation of magmas; pre-Pleistocene glacial periods; the Karroo System. It is also proposed that as an economic study similar to the treatment of iron ores, coal, etc., at earlier Congresses, there should be a report on the gold resources of the world, since, as is well known, South

Africa is the largest individual producer. The Committee of Organization also state in their preliminary circular that they are open to receive further suggestions of special subjects for discussion. It is impossible in the space here available to give a list of the proposed excursions, which are numerous and will be of extraordinary interest. It is possible that the Committee may see their way to extend the sphere of excursions as far as the Zambesi; this part of the programme is to be in the hands of the geologists of Southern Rhodesia.

The Prime Minister of the Union of South Africa for the time being will be Honorary President of the Congress, and Dr. A. W. Rogers, F.R.S., will be President. The General Secretary is Dr. A. L. Hall, P.O. Box 391, Pretoria, to whom all communications should be addressed. Titles of papers intended for presentation and discussion at the Congress should reach the General Secretary before a date to be announced in a later circular: acceptance of a paper for reading, however, does not guarantee its publication.

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THE Geological Survey of Denmark will celebrate its fortieth anniversary in June, by a series of meetings and excursions to which foreign geologists are to be invited. Previous to the meeting in Copenhagen an excursion will be arranged to Bornholm, Denmark's outlying rocky island in the Baltic, which is replete with stratigraphical and all sorts of geological interest. Another party is to visit Moën and Zealand, where remarkable dislocations in the Senonian Chalk can be seen and studied.

The conference will be devoted to lectures and discussions on the geology of Denmark, interspersed with inspections of the Copenhagen museums, with their remarkable collections of minerals, fossils, and all sorts of pre-historic remains. Afterwards, an eleven-day excursion will enable foreign geologists to visit and inspect a wide range of glacial phenomena in Zealand, Funen, and Langeland, as well as on the mainland in Jutland. Full particulars, as to dates, accommodation, and special charges, will be sent on application to the Herr Direkteur, Danmarks Geologiske Undersoegelse, Gammelmont 14, Copenhagen.

ORIGINAL ARTICLES.

Notes on the Family Encrinuridae.

By F. R. Cowper Reed, Sc.D., F.G.S.

It has generally been held that the family *Encrinuridae* contains the four genera *Encrinurus*, *Cybele*, *Cromus*, and *Dindymene*, though *Cromus* is sometimes regarded as only a sub-genus of *Encrinurus*. The distinctive features of *Encrinurus* and *Cybele* as usually understood have been described and discussed by many authors, especially Salter, Nieszkowski, and Schmidt,[1] but in 1877, Woodward[2] considered *Cybele* to be only a sub-genus of *Encrinurus*. *Dindymene* is sufficiently distinct from the others to have had generic rank always accorded to it.

Recently two more genera, *Ectenonotus* Raymond[3] and *Cybeloides* Slocom,[4] have been added to the list, and it will be shown that other generic or subgeneric groups should be established.

(1) The genus *Encrinurus* Emmrich, 1844.

Since Vogdes[5] reviewed the genus *Encrinurus* in 1907, and gave a list of all the then known species, several new species have been described, and some new subgenera or genera have been separated off and established. An attempt was made by Vogdes to classify the species into two groups of generic value to which he applied respectively the names *Encrinurus* Emmr. (sens. restr.) and *Cryptonymus* Eichwald (sens. restr.).[6] According to his principles of classification Emmrich's generic name *Encrinurus* (1844) should be restricted to those species having "the genal angles of the head produced into spines, the pygidium with a many-jointed axis terminating in a long caudal spine or blunt point, with 9–10 pleurae." The following species were quoted by Vogdes as belonging to it :—

E. punctatus Brunn.
E. vigilans Hall.
E. seebachi Schmidt.
E. schisticola Torquist.
E. ornatus Hall.
E. sexcostatus Salt.

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[1] Schmidt, "Rev. Ostbalt. Silur. Trilob. Abt. 1" : *Mem. Acad. Imper. Sc. St. Petersb.*, ser. vii,, vol. xxx, No. 1, 1881, pp. 196, 197, 222 ; ibid., Abt. vi, vol. xx, n.s., No. 8, 1907, pp. 17–22 ; Reed, "Lower Palaeoz. Foss. N. Shan States" : *Palaeont. Ind.*, vol. ii, n.s., Mem. 3, 1906, p. 70.

[2] Woodward, *Cat. Brit. Foss. Crustacea*, Brit. Mus., 1877, pp. 35, 36.

[3] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lxvii, No. 1, 1925, p. 135.

[4] Slocom, *Bull. Field Mus. Nat. Hist.* (*Chicago*), *Geol. Ser.*, vol. iv, No. 3, 1913, p. 63.

[5] Vogdes, "The genus *Encrinurus*" : *Trans. San Diego Soc. Nat. Hist.*, vol. i, No. 2, 1907, pp. 61–78, pls. i–iii.

[6] Woodward in 1877 (*Catal. Brit. Foss. Crustacea, Brit. Mus.*, pp. 24–6) put *Cryptonymus* as a sub-genus of *Asaphus*, giving *A. scutalis* Salter as an example.

Most of these occur in the Ordovician, but *E. vigilans* and *E. ornatus* were mentioned as only found in the Silurian.

Eichwald's name *Cryptonymus* (1840) was employed by Vogdes to mark a distinct generic group of those species possessing the following characters: "Genal angles not prolonged into spines, pygidium with few axial joints and few pleurae." The examples of this group which he gave were the following:—

E. variolaris Brongn.
E. expansus Haswell.
E. obtusus Angelin.
E. laevis Angelin.
E. bowningi Foerste.
E. indianensis Kindle.

In this group Vogdes would also include the trilobites generally placed in the separate genus *Cromus* Barrande. But his system of classification does not appear to be satisfactory even when used by himself, for on a later page in the same communication he changed the species *E. schisticola* to *Cryptonymus,* while *E. tuberculosus* Coll. in one place is associated by him with *E. punctatus* and in another place with *Crypt. indianensis.*

The full generic definitions which he gave (op. cit., p. 67) were as follows: "*Encrinurus* sens. restr. Emmrich, 1844, Cephalic shield semi-lunar, with the genal angles produced into long spines. Glabella clavate; surface of glabella and cheeks tuberculated; glabellar furrows obscure. Thorax with eleven segments; pleurae not grooved; tips notched. Pygidium triangular; axis of many joints, 18–23–30; centre marked by a single row of nodes and terminating in a long caudal spine; pleurae 8–10–12."

Cryptonymus Eichwald, 1840:—"Head-shield semi-circular; genal angles rounded, not produced into spines. Glabella gibbous and overhanging, with obscure furrows. Eyes prominent, smooth. Thorax with eleven segments; pleurae without grooves, notched at ends. Pygidium triangular, convex and rounded at the end, with 9–15 [axial] joints and few pleurae (7 or more)."

Weller[1] in 1907, when describing the trilobites of the Niagaran Limestone in the Chicago area, gave the following definition of the genus *Encrimurus* without alluding to *Cryptonymus.* "Cephalon tuberculated, semi-elliptical in outline, the genal angles produced into spines or not; glabella prominent, pyriform, with three pairs of lateral furrows; free cheeks narrow, separated in front of the glabella by a small rostral plate[2]; posterior limb of the facial sutures cutting the lateral margins just in front of the genal angles; eyes small, more or less elevated on conical prominences or slender stalks. Thorax with eleven segments. Pygidium sub-triangular,

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[1] Weller, *Bull. No.* iv, pt. ii, *Nat. Hist. Surv. Chicago Acad. Sc.,* 1907, p. 257.

[2] Henriksen, "Segmentation of the Trilobite Head": *Medd. Dansk geol. Foren, Kobenhavn.* Bd. 7, 1926, p. 23, fig. 21.

the axis long with many more segments than are present upon the pleura [= pleural lobes]."

Raymond in 1913[1] did not adopt Vogdes' system of classification, or recognize two genera, for he kept the name *Encrinurus* for all the species and included *Cromus* in it, without mentioning *Cryptonymus.*

More recently Etheridge and Mitchell[2] in describing the *Encrinuridae* of Australia in 1915 have kept the genera *Encrinurus* and *Cromus* separate, though they make no reference to Eichwald's generic name *Cryptonymus* or to Vogdes' proposed revival of it in a limited sense, but in 1924 Mitchell[3] adopted Vogdes' views to some extent. The following revised definition of the more important characters of *Encrinurus* was given by these authors : " A pyriform, forwardly inflated glabella, devoid of lateral furrows, highly clothed with tubercles of which five pairs border the axial grooves, and the three pairs of these placed between the anterior and posterior pairs are larger than the others ; facial sutures either openly V-shaped or bi-sigmoidal, meeting anteriorly in the middle line of the glabella and cutting the anterior cephalic margin as a single suture ; eyes pedunculate and facetted ; axial grooves curve outwards to the antero-lateral margins of the cephalon, crossed by the facial sutures, and distinctly divide the free cheeks into two unequal portions ; hypostome subrhomboidal, anteriorly cucullate ; thorax of eleven somites ; pygidium triangular, its axial rings anchylosed, and the pleurae composed of from seven to thirteen or more simple, rounded, and unfurrowed segments."

CHARACTERS OF THE CEPHALON.

The denial of the presence of lateral furrows on the glabella by Etheridge and Mitchell is somewhat surprising, but they declare (op. cit., p. 656) that the supposed short lateral furrows are merely spaces between the large marginal tubercules along the axial furrows of the glabella. In the figures of the Silurian species from New South Wales admitted by these authors to belong to *Encrinurus* there are constantly five pairs of primary tubercules along the axial edge of the glabella.

The species which are described and figured by them are *E. mitchelli* Foerste,[4] *E. bowningnensis* Foerste,[5] *E. silverdalensis* Eth. and Mitch., *E. etheridgei* Mitch., *E. rothwellae* Eth. and Mitch., and *E. duntroonensis* Eth. and Mitch. These authors quote Fletcher's description of the specimens of *E. punctatus* from the Wenlock

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[1] Raymond in Eastman-Zittel's *Textbook of Palaeontology,* 2nd ed., 1913, vol. i, p. 723.

[2] Etheridge, jun., and Mitchell, *Proc. Linn. Soc. N.S. Wales,* 1915, vol. xl, pt. iv, pp. 646–80, pls. liv–lvii.

[3] Mitchell, *Proc. Linn. Soc., N.S. Wales,* vol. xlix, pt. ii, 1924, pp. 45–53.

[4] Foerste, *Bull. Scientif. Lab. Denison Univ.,* vol. iii, 1888, p. 124, pl. xiii, figs. 2, 3, 20.

[5] Ibid., p. 122, pl. xiii, fig. 7.

Limestone in which he says that there are "two or three large tubercules arranged on each side of the lower half of the glabella, occupying the situation of the lateral lobes, the furrows between which are not visible".

On the other hand Etheridge and Mitchell (op. cit., p. 648) would place the British species *E. sexcostatus* Salt. in the genus *Cromus*, believing that Salter himself would have done so if he had been familiar with Barrande's genus. But this conclusion the present author cannot support. *Cromus* was established by Barrande[1] in 1852 for four Bohemian species from Etage E (Ordovician), of which the first described was *C. intercostatus* Barr.,[2] and of this a full and minute description was given. Barrande pointed out the close relations of the genus with *Encrinurus*, but he recognized certain differences in the head-shield, hypostome and pygidium. The presence of four pairs of lateral furrows on the glabella was one of these distinctive features of primary importance, but the characters of the hypostome and pygidium do not show more than minor differences, and in *Cr. intercostatus* the axis has most of the rings discontinuous as in *E. punctatus*, though the tips of the pleurae are free and spinose. The cranidia of *Cr. beaumonti* Barr.[3] and *Cr. bohemicus*,[4] combine some of the characters of the *E. sexcostatus* type with those of the *E. punctatus* group, while the pygidium of *Cr. transiens* Barr.[5] is more like that of the *E. variolaris* group. In spite of Barrande's belief that *Cromus* and *Encrinurus* agree in the course of their facial sutures, the type-species of the genera hardly seem to be identical in this respect, and it should be mentioned that the eyes in *Cromus* are sessile and placed close to the glabella instead of being pedunculate and situated at some distance from it as in *Encrinurus*.

Further remarks on the genus *Cromus* by Etheridge and Mitchell (op. cit., p. 648) state that in general features it resembles *Encrinurus* "particularly in the form of the thoracic segments, test-ornamentation, outline of the pygidium, etc.", but that "the glabella bears four pairs of distinct lateral furrows, the hypostome lacks the forward prolongation of that of *Encrinurus*, the eyes are sessile, poorly developed, and, so far as known, there are but ten segments in the thorax as against eleven in that of *Encrinurus*". Consequently these authors come to the same conclusion as Zittel that the genera should be kept apart, in spite of Raymond[6] in 1913 regarding *Cromus* as a synonym of *Encrinurus*. The supposed occurrence of *Cromus* sens. str. in Australia which is based on De Koninck's identification of specimens from New South Wales, is open to doubt, and the specimen which Chapman[1] described in 1911 as *Encrinurus* (*Cromus*) *spryi* from the Silurian of Victoria is declared by Etheridge and Mitchell (op. cit., p. 653) to belong neither to *Encrinurus* nor *Cromus*, owing to its possession of " two deep transverse sulci above the neck ring interrupted in the middle " which probably represent lateral glabellar furrows. In many respects *E. mitchelli* Foerste[2] is said by Australian palaeontologists to be also very closely allied to *Cromus*, so that there seems to be no marked or recognized line of separation between the genera. It should be remembered that Novak[3] considered *Encrinurus* and *Cromus* to be inseparable on the strength of the similarity of their hypostomes. Frech[4] adopted the same view in 1888, applying the generic name *Encrinurus* to his new species *E. novaki* which he considered to be closely allied to *Cromus beaumonti* Barr., and Gortani[5] in 1909, regarded Frech's species as only a variety of Barrande's species. It will be noted that Vogdes (op. cit., pp. 76, 77) did not apparently attach importance to the presence or absence of lateral furrows on the glabella, for he included all Barrande's species of *Cromus* in *Encrinurus*.

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[1] Barrande, *Syst. Silur. Boheme*, i, 1852, pp. 821–9.

[2] Ibid., p. 824, pl. xliii, figs. 1–5.

[3] Ibid., p. 826, pl. xliii, figs. 6–14; ibid., Suppl., p. 120, pl. ix, figs. 24–6.

[4] Ibid., p. 828, pl. xliii, figs. 15–17; ibid., Suppl., p. 120, pl. ix, figs. 27–31.

[5] Ibid., p. 828, pl. xliii, figs. 18, 19.

[6] Raymond in Eastman-Zittel's *Textbook of Palaeontology*, 2nd ed., 1913, vol. i., p. 723.

It may be observed that Mitchell[6] has lately described a new species of *Encrinurus* (*E. frontalis* n. sp.) as possessing on each side " four conspicuous tubercles . . . separated by pronounced pseudo-glabellar furrows ", but the tubercles would be generally interpreted as true lateral glabellar lobes like those of *Cromus* and the furrows as true lateral furrows. *E. frontalis* is regarded by him as closely allied to *E. mitchelli* which is stated to have less distinct lateral lobes and furrows, and it is also considered " to resemble *E. punctatus* more closely than does any other Australian Encrinurid ". But as above mentioned, *E. mitchelli* is also regarded as closely allied to *Cromus*, and *E. konghsaensis* Reed,[7] from the Silurian of the Northern Shan States is considered by Etheridge and Mitchell to have many points in common with *E. mitchelli*. In this Burmese species as well as in the other un-named form[8] from the Central Himalayas described by the present writer the existence of tuberculiform lateral lobes on the glabella is clearly indicated. Both of these species resemble *E. frontalis* Mitch., *E. punctatus* Brunn., and *E. laevis* Ang.,[1] the latter being a Swedish species from the Silurian, which has likewise three pairs of lateral furrows and tuberculiform lateral lobes.

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[1] Chapman, *Proc. Roy. Soc. Victoria*, vol. xxiv, N.S., pt. ii, 1912, p. 297, pl. lxii, fig. 1.

[2] Foerste, *Bull. Sc. Lab. Denison Univ.*, vol. iii, 1888, p. 124, pl. xiii, figs. 2, 3, 20 ; Etheridge and Mitchell, op. cit., p. 657, pl. liv, figs. 1–5, pl. lv, figs. 1–3, 15, pl. lvi, fig. 10, pl. lviii, fig. 9.

[3] Novak, " Studien an Hypost. iv " : *Sitz. böhm. Gesell. Wiss.*, 1879, pp. 475–83 ; ibid., 1886, p. 429, pl. i, figs. 1–8.

[4] Frech, *Zeitschr. deut. geol. Gesell.*, xxxix, 1887, p. 735, t. xxix, figs. 5–9.

[5] Gortani and P. V. de Regny, " Foss. Neosilur., etc." : *Mem. R. Acc. Sc. Bologna*, ser. VI, t. vi, 1909, p. 28 ; t. i, figs. 27, 28.

[6] Mitchell, *Proc. Linn. Soc. N.S. Wales*, vol. xlix, pt. ii, 1924, p. 51, pl. x, fig. 7.

[7] Reed, " Lower Palaeoz. Foss. N. Shan States " : *Palaeont. Ind.*, N.S., vol. ii, Mem. 3, 1906, p. 133, pl. vii, figs. 21–3.

[8] Reed, " Ordov. and Silur. Foss. Centr. Himalayas " : *Palaeont. Ind.*, ser. XV, vol. vii, Mem. 2, 1912, p. 142, pl. xx, fig. 14.

Amongst most American Silurian species the same type of lobation is present, the lateral lobes being mere nodules or large tubercles, and we do not find that their nature and homology are questioned by American authors. Thus in 1907 Weller[2] definitely mentioned the presence of three pairs of lateral furrows in his definition of the genus, and he figures[3] and describes a species *E. tuberculifrons* showing clearly the three pairs of lateral furrows and lobes.

It is noteworthy that Mitchell himself in 1924[4] in reviving the use of the generic name *Cryptonymus* for certain species of *Encrinurus* on the strength of pygidial characters (see postea) describes and figures five pairs of glabellar furrows in a new species (*Crypt. robustus* Mitchell),[5] though he had declared two pages before in the same paper, that *Cryptonymus* was only separable from *Encrinurus* because of differences in the pygidium. But in 1915, Mitchell (op. cit.) in association with Etheridge had separated *Cromus* generically from *Encrinurus* (with which *Cryptonymus* was then included), because of the presence of lateral glabellar furrows in the former.

The characters of the head-shield of the typical species *E. punctatus* Brunn. are well known,[6] and in the case of the glabella the large lateral tubercles (which seem to differ only in size from those ornamenting the rest of the glabella) have been usually interpreted as representing lateral lobes because of the short lateral furrows or notches which separate them. To regard these nodular structures and the grooves which separate them as of a different nature or origin to the acknowledged lateral lobes and furrows on the glabella of *Cromus intercostatus* (the genotype of *Cromus*) or on the glabella of the Ordovician species *Encrinurus sexcostatus* (which though usually ascribed to *Encrinurus* is recognized as being in many respects related to *Cromus*) seems to be contrary to reason. The earlier forms might be expected to have the segmentation more clearly marked, and the tubercular modification of the lateral lobes and the reduction in size or the obscuration of the lateral furrows of the glabella are nátural developments in the later forms which would result from specialization of the generic characters. Ordo-

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[1] Wigand, *Zeitschr. deut. geol. Gesell.*, xl, 1888, p. 92, t. x, fig. 25.

[2] Weller, *Bull. No.* iv, pt. ii, Nat. Hist. Surv., Chicago, Acad. Sci., 1907, p. 257.

[3] Ibid., p. 259, pl. xxiv, figs. 12, 13.

[4] Mitchell, *Proc. Linn. Soc. N.S. Wales*, vol. xlix, pt. ii, 1924, pp. 46–53.

[5] Ibid., p. 49, pl. x, fig. 3.

[6] Fletcher, *Q.J.G.S.*, vol. vi, 1850, p. 403, pl. xxxii, figs. 1–5. Schmidt, *Rev. Ostbalt. Silur. Trilob.* 1, 1881, p. 225, t. xiv, figs. 11–13, t. xv, fig. 18 ; Wigand, *Zeitschr. deut. geol. Gesell.*, xl, 1888, p. 91, t. x, fig. 23.

vician species, as would be expected on this supposition, have the lateral lobes and furrows of the glabella more clearly recognizable than later members of the genus. Thus *E. striatus* Ang.,[1] from the Leptaena Limestone of Sweden, the allied *E. multisegmentatus* Portl. from the Upper Ordovician of Tyrone,[2] of Girvan,[3] and probably of the Baltic provinces,[4] *E. fallax* Reed [5] from Waterford and the often mentioned *E. sexcostatus* Salt. have the lateral lobes on the glabella well marked with the lateral furrows more or less distinct. The American species *E. vannulus* Clarke,[6] from the Ordovician of Minnesota is similar in this respect, according to Clarke's description. In *E. cristatus* Clarke,[7] which is considered allied to *E. seebachi* Schmidt,[8] the lateral furrows are represented by three deep pits in the axial furrows and these suggest the existence of four pairs of lateral lobes. Although Schmidt does not mention lateral lobes or furrows on the glabella of *E. seebachi* yet one of his figures (op. cit., t. xiv, fig. 21) clearly shows their presence.

It is amongst Silurian forms that we find the greatest difficulty in distinguishing true lateral lobes from tubercles, but in British examples [9] of *E. punctatus* they are generally recognizable, though they are nodular in character and the lateral furrows are much reduced, being mere notches in the sides of the glabella. A study of many specimens from the Wenlock Limestone is sufficient to convince us that we have to deal with true though somewhat modified lateral lobes and furrows and not with mere surface-ornaments.

In *E. variolaris*, on the other hand, which has been taken as the type of *Cryptonymus* by Vogdes and Mitchell, the coarse tuberculation of the surface has quite obscured them, and the lateral furrows are no longer distinguishable, as Salter[10] years ago remarked. An examination of Fletcher's figured specimens[11] shows that this is indeed the case, and we may conclude that the furrows have become obsolete, thus indicating an obliteration of the segmentation usually observable in other species.

The persistence of the lobation in the genus is, however, more general than some authors would concede.[12]

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[1] Warburg, *Bull. Geol. Instit. Upsala*, xvii, 1925, p. 334, pl. xi, figs. 30–3.

[2] Portlock, *Geol. Rept. Londonderry*, p. 262, pl. iii, figs. 6, 11.

[3] Reed, " Lower Palaeoz. Trilob. Girvan " : *Palaeont. Soc.*, 1906, pt. iii, p. 122, pl. xvi, figs. 9–11*a* ; ibid., Suppl., 1914, p. 39, pl. vii, figs. 1–3.

[4] Schmidt, op. cit., p. 227, t. xiv, figs. 14, 15, t. xv, figs. 19, 20.

[5] Reed, *Q.J.G.S.*, lxv, 1899, p. 753, pl. xlix, figs. 9–12.

[6] Clarke, *Final Rept. Geol. Nat. Hist., Minnesota*, vol. iii, 1894, p. 739, text-figs. 56–7.

[7] Ibid., p. 741, text-fig. 58.

[8] Schmidt, op. cit., p. 229, t. xiv, figs. 16–26, t. xv, figs. 21–3.

[9] Fletcher, *Q.J.G.S.*, vol. vi, 1850, p. 403, pl. xxxii, figs. 1–5.

[10] Salter, *Mem. Geol. Surv.*, vol. ii, pt. i, 1848, p. 348.

[11] Fletcher, op. cit., p. 404, pl. xxxii, figs. 6–10.

[12] In a new species, *E. rex* Grabau, which has recently been figured from the Silurian of China (Grabau, " Stratigraphy of China, pt. i, 1923–4 " :

One of the distinguishing characters of the head-shield of the *Encrinuridae* which is generally overlooked or insufficiently emphasized is the presence of a narrow and diminutive median band-like rostral shield (rostrum = epistome), as Henriksen [1] has recently pointed out; it is well seen in *Encrinurus punctatus* and *Cybele bellatula*. Henriksen terms this small plate the "rostrum", and regards the lateral sutures which bound it as the continuations of the facial sutures, the short transverse suture which connects them and separates the "rostrum" from the glabella being termed the "marginal suture". The "rostrum" thus separates the free-cheeks on the doublure. The homology of this "rostrum" with the similar structure in other families of trilobites is carefully pointed out by Henriksen, and attention is directed to the importance of these sutures for the ecdysis.

The characters of the hypostoma are well known in *E. punctatus* and in a few other species, and in all of them there is more or less developed the peculiar anterior projection of the body. Lindström [2] has described the maculae in this species and in *E. obtusus* and *E. laevis*.

CHARACTERS OF THE PYGIDIUM.

With regard to the pygidium of *Encrinurus* (using the generic term in its widest sense) we find that its features have different values attached to them, some authors considering the continuity or discontinuity of the rings or their number to be of primary value, while others regard as of chief importance the number of ribs on the lateral lobes. For the purpose of classification of the species a combination of the axial and pleural characters has generally been utilized. But when these characters are thus employed without reference to those of the head-shield difficulties arise in any scheme.

The use of the names *Encrinurus* and *Cryptonymus* for forms possessing certain differences in the pygidia does not seem justified, as the following examination of the evidence will prove; and at any rate the revival of the name *Cryptonymus* and the complete rejection or partial restriction of the well-established and accepted name *Encrinurus* seems to be most inadvisable, in spite of any question of priority, a point on which there is also no general agreement. As we have mentioned above, Vogdes in 1907 attached primary importance to the characters of the pygidium in his scheme of classification, and grouped the species according to the number of rings on the axis. But this led him to make unnatural associa-

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Geol. Surv. China, p. 438, fig. 297), and put in a new sub-genus *Coronocephalus*, the lobation of the glabella is particularly well developed and demonstrates that the lateral tubercles correspond to true lateral lobes.

[1] Henriksen, *Medd. fra Dansk. geol. Foren.*, Bd. 7, 1926, pp. 22, 23, figs. 20*b*, 21.

[2] Lindström, "Visual Organs of the Trilobites": *Kóngl. Sv. Vet. Akad. Handl.*, Bd. 34, No. 8, 1901, p. 56, pl. iv, figs. 4–17.

tions of species ; and it may be remarked that the precise determination of the number of rings is often a matter of difficulty or uncertainty. The number varies to a certain extent even in individuals of the same species, so that the position of the different species in his scheme is often not easily fixed. Such a basis for classification seems to be of small value for practical purposes in this case, and, moreover, to possess little morphological or phylogenetic significance.

The multiplication of axial rings without a corresponding increase of ribs on the lateral lobes of the pygidium appears to be a very late stage of development in certain families or genera and is of a gerontic nature. Thus Richter[1] has pointed out how that in the Permo-Carboniferous trilobite *Anisopyge perannulata* (Shumard),[2] which is one of the latest known representatives of the whole group and is a highly modified member of the *Proetidae*, there are about thirty rings on the axis of the pygidium and only eight ribs on the lateral lobes, and Girty (op. cit.) remarks that there is a similar very unequal segmentation of the axial and lateral portions of the pygidium in the Himalayan Permo-Carboniferous genus *Cheiropyge*,[3] which Diener thought resembles *Cromus*. In *Encrinurus* we find a similar tendency, for in the Silurian species *E. perannulatus* Mitchell,[4] there are forty-four axial rings, and only thirteen ribs on each side. This want of correspondence between the axial rings and the pleural ribs of the pygidium is seen to be specially marked also in the genus *Phillipsia* amongst the *Proetidae*. But we may doubt if these numerous axial rings represent true segments homologous to those of the thorax, and this suspicion arises particularly in connexion with *Encrinurus*, so that we may conjecture that there has been a secondary subdivision of the original axial annulations, and that their multiplication has taken place independent of the ribs on the pleural lobes. Two or more of the existing axial annulations may thus correspond to one original segment and to one pair of pleurae. Moreover, there seems to be little constancy in the number of axial rings and pleurae even within the limits of the same species, a considerable variation in their number being often noticeable. If they represented a true segmentation we should expect less fluctuation in their number, as well as a closer and more obvious relation between the axial rings and pleurae. The fact that in the typical *E. ornatus* Hall and Whitf.,[5] there are only seven median tubercles along the axis against twenty or more axial rings and that these tubercles correspond in number and position with the pleurae on the lateral

[1] Richter, *Centralb. f. Miner., etc., Jahrg.*, 1925, Abt. B, No. 4, p. 115, text-fig. 6.

[2] Girty, Prof. Paper 58, *U.S. Geol. Surv.*, 1908, p. 506, pl. xvi, fig. 14.

[3] Diener, *Palaeont. Ind.*, ser. xv, Himal. Foss., vol. i, pt. iii, 1897, p. 4, pl. i, figs. 2*a*–*c*.

[4] Mitchell, op. cit., 1924, p. 50, pl. x, fig. 4.

[5] Foerste, *Bull. Sci. Lab. Denison Univ.*, vol. xix, 1919, p. 79, pl. xviii, figs. 9*a*–*b*.

lobes fortifies the contention that there has been a subdivision of the original axial segments without a corresponding increase in the number of true metameres. Many of the axial rings when thus subdivided or multiplied are incomplete, being only indicated on each side of the axial line and not continued across the middle. It is an almost universal character of all the species of *Encrinurus* that the axial rings are more numerous than the pleurae, and there seems to be little or no connexion between the number of rings and the number of pleurae in the pygidium. There is very rarely the same number of each, the axial rings being usually two or three times as numerous. These peculiarities are brought out in the following analyses of the species.

Amongst British Ordovician species of *Encrinurus* the number of pleurae and axial rings, complete or incomplete, is as follows :—

	Pleurae.	*Axial rings.*
E. sexcostatus Salt. . . .	6	20
E. fallax Reed	6	21–25
E. contentus Reed . . .	6	22–26
E. multisegmentatus Portl. . .	9–10	32
,, ,, (Slade var.) .	12	24–30
,, ,, var. *trispinosa*	10–11	22–25
E. multiplicatus Salt. . .	11	28
E. punctatus Brunn. (Girvan var.)	9	18–25

The last-mentioned variety of *E. punctatus* from Girvan which was attributed by the author[1] in 1906 to the Llandovery variety *arenacea* Salter, should probably be separated as a distinct species.

The Irish species, first described as *E. octocostatus* Reed,[2] from the Ordovician of Co. Galway, is now placed in a distinct genus (see *Ectenonotus*).

Of Russian and Scandinavian species, *E. seebachi* Schmidt has nine pairs of pleurae and 30–2 axial rings on the pygidium, *E. schisticola* Tornq. has 7–8 pairs of pleurae, and 14–16 axial rings, and *E. striatus* Ang. has 11–12 pairs of pleurae and 26 axial rings.

Schmidt[3] and Wiman[4] describe the British species *E. multisegmentatus* from the Lyckholm Formation of the Baltic provinces and Tornquist[5] from the Leptaena Limestone of Dalecarlia, but the former does not seem identical with the Irish form, and the Swedish form has been recently referred to *E. striatus* Ang. by

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[1] Reed, " Lower Palaeoz. Trilob. Girvan " : *Palaeont. Soc.*, 1906, pt. iii, p. 121, (pars) pl. xvi, fig. 8.

[2] Ibid., *Q.J.G.S.*, lxvi, 1910, p. 277, pl. xxii, figs. 4*a*, 4*b*.

[3] Schmidt, op. cit., 1881, p. 227, t. xiv, figs. 14, 15, t. xv, figs. 19, 20.

[4] Wiman, *Bull. Geol. Instit. Upsala*, vol. viii, 1907, p. 132, pl. viii, fig. 34.

[5] Tornquist, op. cit., 1884, p. 24, t. i, figs. 18–19.

Warburg.[1] Twenhofel [2] records *E. multisegmentatus* from several horizons in the Ordovician of Anticosti Island without giving figures or descriptions. *E. cybeleformis* Raymond [3] from the Trenton Group appears to be allied to *E. punctatus.*

The same want of correspondence and variation in the number of the axial rings and pleurae is seen amongst the American [4] species from Ordovician beds :—

	Pleurae.	*Axial rings.*
E. vannulus Clarke . . .	6	14–16
E. nodosarius Raym. . .	6	+ 10
E. varicostatus Walc. . .	6	16
E. tuberculosus Collie. . .	8	25
E. vigilans (Hall) . . .	9	18
E. cybeleformis Raym. . .	9	18–19
E. trentonensis Walc. . .	9	+ 23

If we turn now to Silurian representatives of the genus we see the same condition prevailing with few exceptions.

Thus amongst British examples the well-known *E. punctatus* (including its varieties) has 23–30 axial rings, and only 8–9 pleurae. *E. variolaris* has 9–12 axial rings to its 7 pleurae, and *E. magnituberculatus* Reed,[5] has 9–11 axial rings to its 7 pleurae.

Amongst Scandinavian forms we find *E. obtusus* (Ang.) to be unusual in having the same number (10) of complete axial rings as pleurae, according to Schmidt [6] and Wigand,[7] and there is also a median row of a few tubercles on the axis which is very exceptional in species with complete rings. In *E. laevis* (Ang.),[8] the pygidium is said to have not many more axial rings than pleurae which number ten.

The relation between the number of axial rings and the number of pleurae in the pygidium is no more apparent amongst American [9] than amongst British Silurian species, so that it seems that the numbers are practically independent of one another. This is seen by the following examples :—

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[1] Warburg, op. cit., 1925, p. 334, pl. xi, figs. 30–3.

[2] Twenhofel, *Mus. Bull. No.* 3 (*Geol. Surv. Canada*), 1914, pp. 6, 10.

[3] Raymond, *Mus. Bull. No.* 31 (*Geol. Surv. Canada*), 1921, p. 33, pl. xi, fig. 2.

[4] Bassler, *Bull.* 92 *U.S. Nat. Mus.*, vol. i, 1915, pp. 477–80.

[5] Reed, GEOL. MAG., Vol. LXII, No. 728, 1925, p. 72, Pl. II, Figs. 3, 3*a*.

[6] Schmidt, op. cit., 1881, p. 224.

[7] Wigand, *Zeitschr. deut. geol. Gesell.*, vol. xl, 1888, p. 92, t. x, fig. 24.

[8] Wigand, *op. cit.* p. 92, t. x, fig. 25.

[9] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lx, No. 1, 1916, pp. 25, 26, pl. iii, figs. 7, 8.

	Pleurae.	Axial rings.
E. ornatus Hall and Whitf.	7–8	+ 20
E. deltoides Shum.	7	24
E. egani Mill.[1]	6–7	18–20
E. thresheri Foerste	7–8	13–18
E. indianensis Kindle	10	15
E. hillsboroensis Foerste	8	30
E. tuberculifrons Weller[2]	6	15
E. reflexus Raym.	8	30
E. americanus Vogd.	5 or 6	20

Of all the species, Ordovician or Silurian, from any part of the world, *E. elegantulus* Billings, seems to have the smallest number of pleurae, five only being described as present; but its axis has many more rings, of which the first eight are complete, the remainder being discontinuous in the centre, and this space is devoid of tubercles. Thus it seems to be much like *E. cybeleformis* Raym.[3] from the Canadian Ordovician.

Foerste[4] states that the typical *E. ornatus* only occurs in the Cedarville Dolomite of Cedarville, Ohio, and has typically only seven pairs of ribs. It is noticeable that these ribs have a few coarse tubercles on them as in the British species *E. magnituberculatus* Reed, and that the axis has seven median tubercles corresponding to the ribs.

By some authors the continuity or non-continuity of the rings across the axis of the pygidium has been chosen as one means of subdividing the genus *Encrinurus*. Thus Mitchell[5] in 1924 attempted a classification of the species into two groups based on this feature, a method which Barrande had partly adopted in 1852. To those species having continuous rings Mitchell would restrict the name *Cryptonymus* with *C. variolaris* (Brongn.) as the genotype, while those having the rings interrupted wholly or in part are put in the genus *Encrinurus* with *E. punctatus* (Brunn.) as the genotype. The separation of the two groups or genera was made to depend entirely on these characters of the pygidium. While it may be conceded that it is a useful method of classification, we may doubt if it is of much morphological importance or phylogenetic value. We find otherwise non-allied species from different horizons possessing this character, and various stages in the loss of complete annulation can be traced. So far no other author appears to have adopted Mitchell's scheme. Thus Raymond [1] in describing recently a new Ordovician species, *E. nodosarius*, from Tennessee having a pygidium with ten distinct continuous rings on the axis, and several more behind it very close together with six pairs of ribs on the pleural lobes, places it in the genus *Encrinurus* and makes no mention of *Cryptonymus* or of Mitchell's scheme, nor does Warburg [2] refer to it in describing the trilobites of the Leptaena Limestone.

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[1] Weller, *Bull. No.* iv, *pt.* ii, *Nat. Hist. Surv.* (*Chicago Acad. Sc.*), 1907, p. 257, pl. xxiv, figs. 8–11.

[2] Weller, op. cit., p. 259, pl. xxiv, figs. 12, 13.

[3] Raymond, *Mus. Bull.* 31 (*Geol. Surv. Canada*, 1921), Geol. Ser., No. 38, p. 33, pl. xi, fig. 2.

[4] Foerste, *Bull. Sci. Lab. Denison Univ.*, vol. xix, 1919, p. 79, pl. xviii, figs. 9*a*–*b*.

[5] Mitchell, op. cit., 1924, pp. 46–54.

The loss of continuity in the furrows crossing the axis and separating the axial rings seems, in fact, to be a secondary feature, and results in the development of a smooth median space for part of or the whole of the length of the axis. This space may or may not be marked with a line of occasional tubercles.

In certain species, such as the Ordovician *E. sexcostatus* Salt., *E. vannulus* Clarke,[3] and *E. elegantulus* Billings, the anterior axial rings alone are complete and continuous across the axis, while the posterior ones are weakly marked in the middle or incomplete. This seems to be an intermediate stage on the way to the development of an entirely incompletely ringed axis and of a continuous smooth median space.

A similar condition obtains in the form from the Baltic provinces which Schmidt [4] refers to *E. multisegmentatus* Portl., the posterior members of the series of 24–7 axial rings being weak or obliterated in the middle. The same is also found in the Welsh representative of this form from the Slade Beds [5] and in the Girvan variety.[6]

Warburg [7] describes one species *E. striatus* Ang., from the Leptaena Limestone of Sweden which has complete rings for the whole length of its axis, but this seems to be a rare condition amongst Ordovician species. This Swedish form was referred by Tornquist [8] to *E. multisegmentatus* Portl., and there is an allied Russian form, *E. seebachi* Schmidt,[9] which may either have all the rings complete across the axis or they may be more weakly defined in the middle than at the sides, as in the Slade form of *E. multisegmentatus*.

The species of *Encrinurus* from the Stinchar Limestone of Girvan, a pygidium of which was figured by the author in 1906,[10] and ascribed to the Llandovery variety *arenacea* Salt. of *E. punctatus*, has its whole axis composed of complete rings about twenty-five in number; probably this form belongs to a distinct species, and it should undoubtedly be separated from the British Silurian variety bearing that name. For we may doubt if any true variety of *E. punctatus* is found in the Ordovician, in spite of previous references to its occurrence. The specific name *stincharensis* may be suggested for it.

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[1] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lxvii, No. 1, 1925, p. 132, pl. viii, fig. 14.

[2] Warburg, *Bull. Geol. Instit. Upsala*, vol. xvii, 1925, p. 334.

[3] Clarke, " Lower Silur. Trilob. Minnesota " : *Final Rept. Geol. Nat. Hist. Surv. Minnes.*, vol. iii, 1894, p. 739, figs. 56, 57.

[4] Schmidt, op. cit., p. 227, t. xiv, figs. 14, 15, t. xv, figs. 19, 20.

[5] Reed, Geol. Mag., Dec. V, Vol. I, 1904, p. 387, Pl. XII, Fig. 5.

[6] Reed, " Lower Palaeoz. Trilob. Girvan " : *Palaeont. Soc.*, 1906, pt. iii, p. 122, pl. xvi, figs. 9–11*a* ; ibid., Suppl., 1914, p. 39, pl. vii, Figs. 1–3.

[7] Warburg, op. cit., p. 334, pl. xi, figs. 30–3.

[8] Tornquist, *Siljans. Trilobitf.*, 1884, p. 23, t. i, figs. 15–17.

[9] Schmidt, op. cit., p. 229, t. xiv, figs. 16–26, t. xv, figs. 21–3.

[10] Reed, *Lower Palaeoz. Trilob. Girvan*, pt. iii, 1906, p. 121 (pars), pl. xvi, fig. 8.

Of other Ordovician species of the genus *E. multiplicatus* Salt.,[1] from the Middle Bala of Dent, has 16 complete rings on the axis, followed by 12 narrower incomplete ones. *E. contentus* Reed,[2] from Girvan, has 10–12 complete ones followed by 12–14 incomplete ones. In *E. fallax* Reed,[3] from Ireland, there are usually 9–10 continuous rings, followed by 2–5 which are interrupted in the middle, and this seems to be the earliest stage known in the discontinuous condition of the posterior rings.

Of American Ordovician species there is in addition to the above-mentioned *E. vannulus* the Canadian form *E. cybeleformis* Raymond,[4] possessing a similar continuity of the anterior rings followed by a discontinuity of the posterior rings.

We come now to the group of Silurian species possessing complete axial rings for the whole length of the axis. Such are the British and European species *E. variolaris* Brong.,[5] which Mitchell chose as his type of *Cryptonymus*, the English species *E. magnituberculatus* Reed, *E. obtusus* Ang. from Sweden, and the so-called variety *arenacea* of *E. punctatus* from the Llandovery of the Girvan area,[6] and probably some of those thus described by Salter from Wales. All these forms would be placed in the genus *Cryptonymus* by Mitchell,[7] who under this name has described a number of new species from New South Wales, such as *C. platynotus*, *C. incertus*, *C. robustus*, *C. angustus*, *C. perannulatus*, and *C. duntroonensis* Eth. and Mitch.,[8] but these, however, are characterized by much more numerous axial rings and pleurae than in *E. variolaris*.

Amongst the American species of Silurian age of which Raymond [9] gave a list in 1916, *E. indianensis* Kindle, *E. nereus* Hall, and *E. tuberculifrons* Weller, have continuous and complete rings for the whole length of the axis.

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[1] Reed, Geol. Mag., Dec. IV, Vol. VIII, 1901, p. 107, Pl. VII, Fig. 3.

[2] Reed, *Lower Palaeoz. Trilob. Girvan*, Suppl. 1914, p. 39, pl. vi, figs. 11, 12.

[3] Reed, *Q.J.G.S.*, lxv, 1899, p. 753, pl. xlix, figs. 9–12.

[4] Raymond, *Mus. Bull.* 31 (*Geol. Surv. Canada*, 1921), Geol. Ser., No. 38, p. 33, pl. xi, fig. 2.

[5] Fletcher, *Q.J.G.S.*, vol. vi, 1850, p. 404, pl. xxxii, figs. 6–10; Salter, *Mem. Geol. Surv. Doc.*, vii, 1853, art. 4, p. 7, pl. iv, figs. 13, 14.

[6] Nicholson and Etheridge, *Mon. Silur. Foss. Girvan*, fasc. i, 1879, p. 109, pl. viii, fig. 2; Reed, *Lower Palaeoz. Trilob. Girvan*, pt. iii, 1906, p. 120 (non pl. xvi, fig. 8).

[7] Mitchell, op. cit., 1924, pp. 47–50, pl. x, figs. 1–6.

[8] Etheridge and Mitchell, op. cit., 1915, p. 570, pl. lvi, figs. 11, 13. These authors suggest that this species belongs to a new genus, and Vogdes (*Palaeoz. Crustacea, Trans. San Diego Soc. Nat. Hist.*, vol. iii, No. 1, 1917, p. 30) proposed for it the name *Mitchellia*.

[9] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lx, No. 1, 1916, p. 26.

E. indianensis Kindle,[1] from the Niagara of Indiana, has in the pygidium fifteen continuous rings across the axis, and ten pleurae, and in some respects it approaches *E. variolaris*, but it has more numerous axial rings and pleurae and more tubercles (five instead of three) on the axial rings. The head-shield has three large lateral tubercles ("pseudo-lobes") on each side of the glabella, and the coarse tuberculation is also much like that of *E. variolaris*.

There is another group of chiefly Silurian species in which the axial rings of the pygidium are interrupted and discontinuous, the smooth central space thus formed along the axis being ornamented with a line of a few regularly placed tubercles. This group comprises *E. punctatus* Brunn.[2] with its variety *calcarea*, but apparently not the so-called variety *arenacca* (as above mentioned). There is considerable diversity in the pygidia ascribed to this species, as Schmidt[3] has remarked. The Swedish species *E. laevis* Ang.[4] also belongs here. This seems to be the extreme stage of the modification of the axis of the pygidium amongst members of the genus.

In America this group is represented by the following species: *E. deltoides* Shum, *E. egani* Miller, *E. ornatus* Hall and Whitf.,[5] *E. thresheri* Foerste, *E. reflexus* Raym., *E. hillsboroensis* Foerste. The typical form of *E. ornatus* has a median line of seven tubercles on the axis corresponding to the seven ribs on the lateral lobes, but each to 2–3 of the narrow interrupted axial rings.[6] *E. reflexus* Raymond[7] from the Niagaran of Wisconsin, has the obtuse tip to the pygidium found in the var. *arenacea* of *E. punctatus*, but it possesses the smooth median space with the tubercles and interrupted rings of the var. *calcarea*. *E. hillsboroensis* Foerste[8] seems practically indistinguishable from the latter.

In Australia *E. silverdalensis* Eth. and Mitch.[9] and *E. mitchelli* Foerste[10] are examples of the same type of axial modification, and have a median line of tubercles.

It is remarkable that in *E. obtusus* Ang., which is the Swedish

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[1] Kindle, 28*th Ann. Rept. Indiana Geol. Surv.*, 1903, (1904), p. 482, pl. xxiv, figs. 14, 15.

[2] The typical *E. punctatus* of Europe does not seem to occur in America in spite of Van Ingen's statement (*School of Mines Quarterly*, vol. xxiii, 1901, No. 1, p. 66) and Twenhofel's more recent record of it (*Mus. Bull. No.* 3, *Geol. Surv. Canada*, Geol. Ser., No. 19, 1914, pp. 14, 16).

[3] Schmidt, op. cit., p. 225, t. xiv, figs. 11–13, t. xv, fig. 18.

[4] Lindström, *Ofv. K. vet. Akad. Forhandl.*, 1885, No. 6, p. 52, t. xiii, fig. 7.

[5] Swartz and Prouty, *Geol. Surv. Maryland, Silurian*, 1923, p. 705, pl. xxxiii, figs. 9, 10, and references.

[6] Foerste, *Bull. Sc. Lab. Denison Univ.*, vol. xix, 1919, p. 79, pl. xviii, figs. 9*a*–*b*.

[7] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lx, 1916, No. 1, p. 25, pl. iii, figs. 7, 8.

[8] Foerste, *Ohio Journ. Sc.*, vol. xix, No. 7, 1919, p. 391, pl. xviii, figs. 2*a*–*c*.

[9] Etheridge and Mitchell, op. cit., 1915, p. 665, pl. lv, figs. 4, 9, pl. lvi, figs. 4, 5, 6, 14, pl. lvii, figs. 3, 10; Mitchell, op. cit., 1924, p. 52, pl. x, fig. 13.

[10] Foerste, *Bull. Sc. Lab. Denison Univ.*, iii, pt. ii, 1888, p. 124, pl. xiii, figs. 2, 3, 20; Mitchell, op. cit., 1924, p. 52, pl. x, figs. 12, 14, and references.

Silurian species of the *E. variolaris* group having the continuous and complete rings across the axis, there is also a median row of tubercles without any smooth space. This suggests that the tubercles are earlier in origin than the smooth space, and the conclusion seems supported by the numerical correspondence of the tubercles with the pleurae and not with the rings in certain species.

The pleurae of the pygidium in all the species, except those attributed to *Cromus*, end bluntly on the margin, but retain their individuality to their tips, no weakening of the intercostal furrows or development of a border being found. But in *Cromus* they are more or less produced beyond the general edge of the pygidium as free spines.

CONCLUSIONS.

From the foregoing examination and comparison of the various species of *Encrinurus* sens. ext. from Ordovician and Silurian rocks, it is seen that the classification of them in a natural and satisfactory manner is a matter of some difficulty, whether we take the head-shield or the pygidium as our basis. When we take both parts into consideration the difficulty does not wholly disappear, for the inter-relations of the species and combinations of differences of structure are complicated and parallelism seems often to have prevailed. *Cromus* seems to be hardly separable, even as a sub-genus, on account of its many and diverse relationships.

We may, however, recognize the following groups which appear to rest on morphological features, and to possess a certain phylogenetic significance.

(1) Pygidium with complete axial rings, considerably more numerous than the pleurae. Cephalon with distinctly lobed glabella, lateral furrows clearly marked; lateral lobes sometimes nodular. Genal angles pointed. Example: *E. sexcostatus* Salt. Range: chiefly Ordovician.

(2) Pygidium with complete axial rings, few and equal in number to or not much more numerous than the pleurae. Cephalon coarsely tuberculated, with lateral lobes and furrows of glabella obscure or absent. Genal angles rounded. Example: *E. variolaris* Brongn. Range: Silurian.

(3) Pygidium with very numerous complete axial rings. Pleurae fewer in number than rings. Cephalon coarsely tuberculated. Lateral lobes of glabella nodular. Example: *E. platynotus* Mitch. Range: Silurian. (This group seems to be chiefly Australian.)

(4) Pygidium with numerous rings on axis, of which the anterior rings are complete, but the posterior ones are interrupted or weakly marked in the middle. Cephalon with glabella coarsely tuberculated; lateral lobes nodular. Example: *E. multisegmentatus* Portl. Range: Upper Ordovician.

(5) Pygidium with very numerous narrow axial rings, all (or nearly all) incomplete and discontinuous, with smooth median

space for whole length of axis, usually ornamented with row of tubercles fewer in number than the rings. Cephalon with glabella coarsely tuberculated and lateral lobes usually nodular. Example: *E. punctatus* Brunn. Range: Silurian.

(6) Pygidium with axial rings continuous or discontinuous. Pleurae with free spinose ends. Cephalon with glabellar furrows distinct. Eyes sessile, close to glabella. Thorax of ten segments. Type: *Encrinurius* (*Cromus*) *intercostatus* Barrande. Range: Silurian.

There are some species which it is difficult to assign to any one of these groups, and the existence of such intermediate or transitional forms renders it unsafe and practically impossible to regard the above groups as of subgeneric or generic rank, though their stratigraphical range is rather strictly limited, and they seem to mark stages in the evolution of the genus. The final stage morphologically seems to be the fifth or *E. punctatus* group, which may be derived from the fourth or *E. multisegmentatus* group.

The second or *E. variolaris* group may be in phylogenetic relation to the first or *Cromus*-like group.

The third group is chiefly developed in Australia, but has a few representatives in North America and Europe. It appears to be a Silurian development of the fourth group, with reversionary or more primitive characters in the axis of the pygidium. It is probable that Grabau's Chinese species *E.* (*Coronocephalus*) *rex* should constitute another group, or even be regarded as of generic rank.

The British species which have been from time to time referred to the genus *Encrinurus* are the following:—

ORDOVICIAN.	*E. sexcostatus* Salter.
	E. multisegmentatus Portl.
	,, ,, var. *sladensis* Reed, 1904.
	,, ,, var. *trispinosa* Reed, 1914.
	E. multiplicatus Salt.
	E. fallax Reed.
	E. contentus Reed.
	[*E. octocostatus* Reed.]
	E. punctatus var. *arenacea* Salt. (?). (*E. Stincharensis* nom. prop.)
SILURIAN.	*E. punctatus* Brunn.
	,, var. *calcarea* Salt.
	,, var. *arenacea* Salt.
	E. variolaris Brongn.
	E. magnituberculatus Reed.

There is a peculiar pygidium from the Ordovician of Connemara which the author[1] described in 1909 as *Cybele connemarica*, but it is unlike any other species attributed to that genus, especially differing in the large number (nine or ten) of its pleurae which also are simple, as in *Encrinurus*. It was erroneously considered to be allied to

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[1] Reed, *Q.J.G.S.*, lxv, 1909, p. 146, pl. vi, figs. 6, 7.

Cybele bellatula Dalm., but it may undoubtedly be referred with far greater probability to the genus *Encrinurus.*

The above-mentioned British species may be distributed as follows amongst the different groups above suggested :—

Group 1.	*E. sexcostatus* Salt.
	E. fallax Reed.
	E. contentus Reed.
Group 2.	*E. variolaris* Brongn.
	E. magnituberculatus Reed.
Group 3.	*E. punctatus* var. *arenacea* Salt.
Group 4.	*E. multisegmentatus* Portl.
	E. multiplicatus Salt.
Group 5.	*E. punctatus* Brunn.

It is held that Group 3 is represented by the Silurian form *E. punctatus* var. *arenacea* Salt., but this variety should probably be regarded as of specific rank as well as the Ordovician form on the strength of the pygidial characters. *E. octocostatus* is now removed to the new genus *Ectenonotus* established by Raymond, as described below.

(2) Genus *Ectenonotus* Raymond, 1920.

A new genus named *Ectenonotus* was established by Raymond[1] in 1920 to contain the species *Amphion westoni* Billings,[2] because it possessed an *Encrinurus*-like pygidium combined with a cephalon having some of the characters of *Pliomerops.* The pygidium has a narrow elongate form with a very long axial lobe (axis) composed of numerous complete and continuous rings ; the pleural lobes consist of ten pairs of ribs, of which the last four curve back inwards behind the end of the axis. The cephalon has a glabella possessing the form and lateral furrows of *Cybele bellatula*, and the glabella does not expand towards the front as in *Pliomerops* nor is the eye situated close to the glabella as in that genus. Billings founded his species on a cranidium from Canada, but Raymond[3] prefers to take the specimen from Newfoundland with the thorax and pygidium as the holotype of the genus. According to Raymond (op. cit., p. 138) the trilobite from Glensaul described by the author in 1910 as *Encrinurus octocostatus*[4] is referable to this new genus, and with it he would associate with probable justification the head-shields from the same locality described by the author as *Pliomera pseudoarticulata* (Portl.),[5] for there is a close resemblance between them and the Canadian species. As regards the pygidium there are about twenty-one rings on the axis of *E. westoni* with ten pleurae on each side, but in *E. octocostatus* there are only ten rings on the axis, and eight pairs of pleurae.

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[1] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lxiv, No. 2, 1920, p. 295.

[2] Billings, *Pal. Foss. Canada*, 1865, i, p. 321, figs. 307*a–b*.

[3] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lxvii, No. 1, 1925, pp. 135–8.

[4] Reed, *Q.J.G.S.*, vol. lxvi, 1910, p. 277, pl. xxii, figs. 4*a–b*.

[5] Ibid., p. 276, pl. xxii, figs. 5, 6.

(3) The genus *Encrinurella* Reed, 1915.

In 1915, the present author [1] placed the Burmese trilobite which he had previously described as *Pliomera insangensis* Reed [2] in a new subgenus of *Pliomera* which he termed *Encrinurella.* The only well-known representative of it is this species from the Ordovician of the Northern Shan States which has been fully described and its relations discussed by the author, but it is possible that the head-shield from the Ordovician of Yunnan which the author named *Pliomera martellii* [3] and regarded as resembling the Burmese form in some respects may also be ascribed to this genus. The species *Pl. insangensis* combines some characters of *Pliomerops* [4] with some of *Encrinurus*, the glabella being much like the latter while the pygidium has some of the characters of the former; the thorax also seems to resemble *Pl. linnarssoni* Wiman rather than any species of *Encrinurus*, and the Canadian species *Pliomerops canadensis* (Billings) [5] appears also to bear a very close resemblance. On the whole *Encrinurella* seems worthy of generic rather than subgeneric rank and may be associated with the *Encrinuridae* rather than with the *Cheiruridae* in spite of its pygidium.

It is deserving of notice in this place that several genera seem to link together the *Cheiruridae* and *Encrinuridae* as usually understood, and the position of some has been a matter of dispute. Thus Barrande placed *Amphion* (= *Pliomera*) in the *Encrinuridae*, though it is now generally associated with the *Cheiruridae. Ectenonotus*, as Raymond has pointed out, has a head-shield and glabella more like *Pliomera* than *Encrinurus*, but a pygidium more like *Encrinurus*, while in *Encrinurella* the affinities of these two parts of the body are the reverse, the head and glabella being more like *Encrinurus*, and the pygidium more like *Pliomera* or *Pliomerops.* The thorax of all four genera is much alike, especially in the character of the pleurae.

It will be described further on how members of one group of species of *Cybele* have likewise a head-shield, glabella and facial sutures possessing many of the characters of *Pliomera.*

The typical *Cheirurus* (*Ceraurus*) must have diverged at an early stage from the original stock from which the *Encrinuridae* and *Pliomerinae* also arose, but that they had a common ancestor is highly probable, and Barrande long ago recognized their intimate relations.

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[1] Reed, "Suppl. Ordov. Silur. Foss. N. Shan States": *Palaeont. Ind.*, N.S., vol. vi, No. 1, 1915, p. 50, pl. viii, figs. 15–21.

[2] Ibid., "Lower Palaeoz. Foss. N. Shan States": *Palaeont. Ind.*, N.S., vol. ii, Mem. No. 3, 1906, p. 74, pl. v, figs. 19–25.

[3] Ibid., "Ordov. Silur. Foss. Yunnan": *Palaeont. Ind.*, N.S., vol. vi, Mem. No. 3, 1917, p. 55, pl. viii, figs. 15, 16.

[4] Raymond, *Amer. Journ. Sc.*, vol. xix, 1905, p. 377.

[5] Raymond, *Ann. Carnegie Mus.*, vol. vii, No. 1, 1910, p. 75, figs. 3–8, pl. xviii, fig. 14; ibid., *7th Rept. Vermont. State Geol.*, 1910, p. 238, pl. xxxvi, figs. 10–13; ibid., *Bull. Mus. Comp. Zool. Harvard*, vol. lxvii, No. 1, 1925, p. 152.

(4) The genus *Cybele* Lovén, 1845.

The characters of the genus *Cybele* have been well described by Schmidt,[1] but it does not seem to be a homogeneous genus. All its representatives occur in the Ordovician, none ranging up into the Silurian. The genotype is *C. verrucosa* Dalman. Schmidt recognized three groups amongst the species occurring in the Baltic provinces, the first containing *C. bellatula* Dalm.[2] (non Schmidt, 1881) characterized by having five pleurae on the pygidium and only a single tubercle on the margin in front of the glabella. The second and third groups have only four pleurae on the pygidium but a greater number (at least five) of tubercles or teeth on the margin in front of the glabella. The members of the second group, which comprises *C. worthi* Eichw., *C. affinis* Schmidt, *C. kutorgae* Schmidt, and *C. brevicauda* Ang., have the glabella widening anteriorly and bearing scattered tubercles. In the third group the glabella is parallel-sided, not widening in front, and has 3–4 pairs of tubercles regularly disposed on it, and this group contains *C. revaliensis* Schmidt, *C. rex* Nieszk., *C. grewingki* Schmidt, and *C. coronata* Schmidt. To the second group Schmidt would also ascribe *C. aspera* Linnarss. and *C. verrucosa* Dalm., but *C. dentata* Esm. he would put in the third group. *C. loveni* Linnarss. was considered to belong to an independent division.

The position of the eyes is a character of much importance, which Schmidt hardly seems to have sufficiently emphasized in the above scheme of classification, and his groups become more securely based when we take these and other characters of the head-shield into account.

Henriksen[3] has recently drawn attention to the peculiar nature of the rostral shield (= rostrum = epistome) and to its significance, and as above mentioned in the case of *Encrinurus* he regards the short lateral sutures which cut off the "rostrum" from the doublure as the anterior terminal portions of the facial sutures. But it is more convenient to term them the rostral sutures, while admitting that they form part of the facial sutures.

The characters of the groups thus recognized by Schmidt may be summarized as follows :—

Group I.—Glabella oval or sub-oblong, with three pairs of well-marked lateral furrows, the anterior pair situated far forward. Eyes placed very far forward but not far distant from sides of glabella. Facial sutures with anterior branches short, strongly convergent. Rostral sutures short, parallel, very close together; rostral shield very small, longer than broad. Cheeks tuberculated. Type : *C. bellatula* Dalm.

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[1] Schmidt, "Rev. Ostbalt. Silur. Trilob. Abt. 1": *Mem. Acad. Imper. Sc. St. Petersb.* ser. VII, vol. XXX, No. 1, 1881, pp. 197–222; ibid., Abt. VI, op. cit., N.S., vol. XX, No. 8, 1907, pp. 17–21.

[2] Schmidt in 1907 transferred the Russian form which he had identified as *C. bellatula* into a new species *C. panderi*.

[3] Henriksen, *Medd. fra Dansk. geol. Foren. Kobenhavn*, Bd. 7, 1926, pp. 22, 23, fig. 20*b*.

Group II.—Glabella subquadrate to subpyriform, with frontal lobe more or less transversely expanded ; lateral furrows short, anterior pair situated at one-third (or more) the length of glabella from front end. Eyes sub-central or behind centre, at some distance from sides of glabella. Facial sutures with anterior branches slightly convergent. Rostral sutures far apart, short ; rostral shield short, transverse, broader than long. Cheeks tuberculated. Genal angles broadly rounded. Type : *C. wörthi* Eichwald.[1]

Group III.—Glabella subquadrate ; lateral furrows usually represented by isolated pits. Eyes situated far forward, submarginal, wide apart, usually connected with glabella by ocular ridge. Preglabellar margin furnished with spinose fringe or pointed tubercles. Glabella with 3–4 pairs of regularly disposed tubercles on surface. Cheeks finely pitted and having only a few scattered tubercles. Genal angles produced. Rostrum and rostral sutures unknown. Type : *C. rex* Nieszkowski.[2]

By means of these characters we can classify the species described by Schmidt as follows :—

Group I.	*C. panderi* Schm.
	C. bellatula Dalm.
Group II.	*C. wörthi* Eichw.
	C. affinis Schm.
	C. kutorgae Schm.
Group III.	*C. rex* Nieszk.
	C. coronata Schm.

There are some species not included in the foregoing list, which have intermediate or composite characters. Thus in *C. revaliensis* Schmidt [3] and *C. grewingki* Schmidt,[4] we seem to have a sub-group of *C. rex*, for the eyes are placed far back and sub-centrally as in Group II, the anterior branches of the facial sutures are convergent as in the same group and the marginal fringe is reduced to a few tubercles. But the pitting of the cheeks, the shape, lateral furrows and lobes of the glabella, the paired tubercles on it and the ocular ridges are more as in Group III.

The genotype of *Cybele*, *C. verrucosa* Dalm.,[5] clearly belongs to

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[1] Schmidt, op. cit., 1881, p. 214, t. xiii, figs. 14–17.

[2] Schmidt, op. cit., 1881, p. 209, t. xiii, figs. 21–3 ; t. xiv, figs. 3, 4 ; t. xv, figs. 8, 9. Krause, " Geol. Alter der Backsteinkalk " : *Abhandl. k. geol. Landesanst.*, Bd. xv, 1894, p. 134, t. v, fig. 6.

[3] Schmidt, op. cit., p. 207, t. xiii, fig. 20 ; t. xiv, fig. 6 ; t. xv, figs. 6, 7 ; t. xvi, fig. 40.

[4] Ibid., p. 211, t. xiv, figs. 1, 2, text-fig. 11. Wigand, *Zeitschr. deut. geol. Gesell.*, xl, 1888, p. 89, t. x, fig. 17.

[5] Loven, *Ofv. k. svensk. vet. Akad. Forhandl.*, 1845, No. 3, p. 52, pl. i, figs. 5a–c. Salter, *Mem. Geol. Surv., Gt. Britain*, vol. iii (2nd ed. 1881), p. 522, pl. xix, fig. 7.

Group II; and *C. brevicauda* Ang. and *C. adornata* Törnq.[1] (which is allied to *C. wörthi* and *C. affinis*) are also referable to it.

The Swedish species *C. aspera* Linnarss.[2] must be regarded as more or less intermediate in character between Groups II and III, but it belongs to another branch; the cheeks are tuberculated, there are no ocular ridges, and there are only pointed tubercles on the preglabellar margin not forming a fringe, but it resembles Group III in the lateral furrows being represented by pits and in the eyes being far forward and widely separated.

There is a quite distinct group of species constituting a separate sub-genus or genus, which is not represented in the Russian Ordovician, but occurs in Sweden and in the British Isles. *C. loveni* Linnarss.[3] is a typical example of it. In this the glabella is tripartite, the lateral lobes on each side being more or less fused together longitudinally, but individually marked off mainly by isolated pits; the eyes are placed far back or sub-centrally; the glabella is subquadrate or sub-pentagonal, the anterior margins of the cheeks arch forward and project on each side so that the front edge of the head-shield is emarginate. The thorax has the posterior pleurae developed into long spines, and the pygidium seems to have only three complete pleurae. The whole of the characters of this species precisely resemble those of the genus or sub-genus *Cybeloides*, established by Slocom (see below) for certain American species usually placed in *Cybele*, and the glabella of *C. loveni* specially recalls that of *C. primus* (Raym.),[4] which belongs to the genus or sub-genus *Cybeloides* (see below).

Amongst British species of *Cybele* we have Group I represented by a Girvan form [5] referred to *C. bellatula* Ang. on the strength of Schmidt's [6] figures and description published in 1881. But in 1907, Schmidt declared that his specimens were distinct from the true *C. bellatula*, and therefore gave them the new specific name *panderi*,[7] so that our Girvan examples should now bear this designation. A variety named *balclatchiensis* [8] was also described in 1914 from the Girvan district. It is probable that the cranidium figured by the author from the same beds as *Cybele* sp. a.[1] is referable to *C. bellatula* as redefined by Schmidt.[2]

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[1] Tornquist, "Undersokn. Siljans. Trilobitf.": *Sver. Geol. Undersokn.*, ser. c, No. 66, 1884, p. 25, t. i, figs. 20, 21. Wiman, *Bull. Geol. Instit. Upsala*, vol. viii, 1907, p. 107, pl. vii, figs. 13, 14.

[2] Linnarsson, *Kongl. Vetensk. Akad. Handl.*, viii, No. 2, 1869, p. 62, t. i, figs. 11–13.

[3] Ibid., p. 63, t. i, fig. 14.

[4] Raymond, *Ann. Carnegie Mus.*, vol. iii, 1905, p. 362, pl. xiv, figs. 6, 7; ibid., p. 362, pl. xiv, fig. 9 (*C. valcourensis*); ibid., vol. vii, 1910, p. 75, pl. xix, fig. 19; ibid., *7th Rept. Vermont State Geol.*, 1910, p. 237, pl. xxxvi, figs. 7–9.

[5] Reed, "Lower Palaeoz. Trilob. Girvan": *Palaeont. Soc.*, pt. iii, 1906, p. 124, pl. xvi, figs. 14–17.

[6] Schmidt, op. cit., p. 203, t. xiii, figs. 9–13, t. xv, figs. 1–5.

[7] Schmidt, op. cit., Suppl. 1907, p. 19.

[8] Reed, op. cit., Suppl. 1914, p. 41, pl. vii, fig. 6.

In Group II we have *C. verrucosa* Dalm. which has long been known from various British localities for Ordovician rocks and has been described by Salter,[3] McCoy,[4] and others.[5] In this Group II we may place also *C. michelli* Reed,[6] from the Girvan area, based on a head-shield, while Group III is represented by the peculiar species *C. tramorensis* Reed,[7] from Co. Waterford, and probably by *C. sextuberculata* Reed,[8] from the same locality.

The form from the Balclatchie beds, Girvan,[9] which was compared by the author with *C. aspera* Linn. is only represented by two head-shields which possess the typical character of this rather isolated species.

C. loveni Linnarss. var. *girvanensis* Reed,[10] from the uppermost Ordovician of Girvan, which is known as the best preserved British member of the genus, being represented by complete individuals, shows all the important characters of Linnarsson's Scandinavian species, and therefore belongs to Group IV. To this group also belongs *C. rugosa* Portlock,[11] from Tyrone, a species closely allied to *C. loveni*.

The imperfectly known species from Tramore named *C. McHenryi* Reed,[12] has a shield suggesting its reference to Group I, but its position is doubtful.

The hypostome of the various species of *Cybele* is not as a rule known, but Lindström[13] figures one of *C. bellatula* Dalm., which shows that its characters are quite distinct from those of *Encrinurus punctatus*, *E. obtusus*, and *E. laevis*.

Isolated pygidia are usually difficult to allocate when they do not exactly agree with well-known species. The modification of the pygidium and its phylogenetic development do not always seem to have proceeded on the same lines in the different groups, but to have occasionally followed an independent course, and separate pygidia are therefore difficult to associate with the several types of head-shields. *C. brevicauda* Ang. was based on a pygidium as Warburg remarks,[1] but Schmidt,[2] refers to it (with a query) certain head-shields from the Upper Ordovician, and on the strength of their likeness in many respects to *C. kutorgae* the species may be placed in Group II.

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[1] Ibid., pt. iii, 1906, p. 130, pl. xvii, fig. 5.

[2] Schmidt, op. cit., Suppl. 1907, p. 17, t. i, figs. 13–15.

[3] Salter, *Mem. Geol. Surv.*, vol. ii, pt. i; 1848, p. 343, pl. viii, fig. 9 (non 10); ibid., vol. iii, 1886, p. 324, pl. xix, fig. 7.

[4] McCoy, *Syn. Palaeoz. Foss. Woodw. Mus.*, fasc. i, 1851, p. 156, pl. iG, figs. 1–5.

[5] Reed, op. cit., 1906, p. 129.

[6] Reed, op. cit., Suppl. 1914, p. 42, pl. vii, fig. 7 (? ibid., 1906, p. 130, pl. xvii, fig. 8, *Cybele* sp. ind. pygidium).

[7] Reed, GEOL. MAG., Dec. IV, Vol. II, 1895, p. 49, pl. iii, fig. 1; ibid., *Q.J.G.S.*, lv, 1899, p. 750, pl. xlix, fig. 6.

[8] Reed, op. cit., 1899, p. 752, pl. xlix, fig. 8.

[9] Reed, op. cit., 1906, p. 128, pl. xvi, figs. 12, 13.

[10] Reed, op. cit., 1906, p. 126, pl. xvii, figs. 1–4; ibid., Suppl. 1914, p. 40, pl. vii, figs. 4, 5.

[11] Portlock, *Geol. Rep. Londond.*, p. 302, pl. v, fig. 10.

[12] Reed, op. cit., 1899, p. 751, pl. xlix, fig. 7.

[13] Lindström, "Visual Organs of Trilobites": *K. Sv. Vet. Akad. Handl.*, Bd. 34, No. 8, 1901, p. 52, pl. iv, fig. 2.

As above remarked, the isolated pygidium from the Ordovician of Galway which the author described in 1909 as *Cybele connemarica*,[3] may more probably be referred to the genus *Encrinurus*, because of its numerous and simple pleurae on the lateral lobes; but to which group it belongs cannot be decided.

Just as in the case of *Encrinurus* we find in *Cybele* that the number of the axial rings on the pygidium varies, and in some cases we likewise find some of them complete and continuous while in others they are incomplete and interrupted in the middle. But there does not appear to be any regular or constant association of any one condition with the several types of head-shields, and the group-reference of any species cannot therefore be determined by the pygidium. The axial rings may number as many as eighteen, and be complete and continuous for the whole length of the axis as in *C. aspera*, or the anterior ones (usually four) may be complete and the posterior ones incomplete leaving a smooth median space down the centre, as is generally the case in Groups II and III, e.g. *C. wörthi*, *C. kutorgae*, *C. grewingki*, *C. rex*; or the posterior ones may be very faintly marked, as in *C. revaliensis*. The posterior smooth median area of the axis between the incomplete axial rings may bear a series of a few tubercles, such as is found in *C. brevicauda* Ang. (compare *E. punctatus*).

With regard to the pygidial pleurae the number is usually four, and these correspond to the four complete anterior axial rings. This may be well seen in *C. rex*, *C. grewingki*, *C. coronata*, and *C. kutorgae*. But in *C. bellatula* there are five instead of four pairs of pleurae, which was one of the reasons which made Schmidt put it in a group by itself, and the axis in this species also has either no complete rings or only one at the anterior end. These are additional reasons for putting it in a group by itself.

In Group IV, containing only *C. loveni*, the pygidium has only three pairs of complete pleurae, the fourth being reduced to a half pleura. In this species the smooth median space extends the whole length of the axis, all the rings being discontinuous and incomplete, and it may bear a series of tubercles as in *C. brevicauda*.

The distal ends of the pleurae in the various species are usually blunt and not free, ending abruptly in a line and lying close together, but they may be free, spinose, and recurved as in *C. coronata*, thus being comparable to the *Cromus* group in *Encrinurus*.

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[1] Warburg, op. cit., 1925, p. 337, pl. xi, fig. 38.

[2] Schmidt, op. cit., 1881, p. 219, t. xi, fig. 23, t. xiv, figs. 7–10; t. xv, figs. 15–17.

[3] Reed, *Q.J.G.S.*, lxv, 1909, p. 146, pl. vi, figs. 6, 7.

The thorax is not known in a sufficient number of species to institute a comparison between the various groups, but the elongated free spinose ends of some of the pleurae in *C. loveni* and in its variety *girvanensis* recall *Dindymene* and members of the *Acidaspidae*.

The genus *Cybele* is typically European, and seems to be very rare in America. Ruedemann[1] and Raymond[2] have recently referred to it the species described by Billings as *Encrinurus mirus* and the latter has also described a new species from the Trenton as *C. spicata*[3] which may be placed in Group III, being allied to *C. rex*.

The other American species of *Cybele* are now referred to the genus or sub-genus *Cybeloides* which was established by Slocom[4] in 1913 with *C. iowensis* Slocom[5] as the genotype. We must include in it *C. ella* Narr. and Raym.,[6] *C. primus* (Raymond)[7] and *C. winchelli* (Clarke).[8] It is on the characters of the head-shield that this genus chiefly rests, and they are sufficiently peculiar to warrant its recognition. Slocom (op. cit.) defines this new genus as follows: " Body distinctly trilobate; outline, aside from the spines, subovate. Cephalon sublunate; genal angles produced into spines. Glabella divided by two longitudinal furrows into a central and two lateral lobes; the lateral glabellar furrows are indicated by three pits situated in each longitudinal furrow. Eyes small, pedunculate; the facial sutures originate on the lateral margins somewhat in front of the genal angles. Thorax consists of twelve segments, the five anterior segments are faceted at their distal extremities, the sixth (and in some specimens the sixth to the twelfth) is abruptly bent backward at the lateral margin of the thorax and produced into long spines. Pygidium small, axis conical with many annulations, pleural lobes with few ribs." The pygidium of the type is unfortunately too poorly preserved for a detailed description. But the reduction in the number of the pleurae suggests the same course of evolution as in *Dindymene*. There can be but little doubt that the European species *Cybele loveni* belongs to the same group or sub-genus as the American *Cybeloides iowensis*. In the characters of the glabella and head-shield as well as in the peculiar development of the thoracic pleurae as described by Linnarsson (op. cit.) we find essential agreement.

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[1] Ruedemann, *Bull.* 49 *New York State Mus.*, 1901, p. 66.

[2] Raymond, *Bull. Mus. Comp. Zool. Harvard*, vol. lxvii, No. 1, 1925, p. 135.

[3] Raymond, *Mus. Bull.* 31, *Geol. Surv. Canada*, Geol. Ser., No. 38, 1921, p. 34, pl. xi, fig. 1.

[4] Slocom, *Bull. Field Mus. Nat. Hist. (Chicago)*, Geol. Ser., vol. iv, No. 3, 1913, p. 63. Bassler, *Bull.* 92 *U.S. Nat. Mus.*, 1915, p. 324.

[5] Ibid., p. 64, pl. xvi, figs. 1–4. Raymond, op. cit., 1925, p. 133, pl. ix, fig. 8.

[6] Narraway and Raymond, *Ann. Carnegie Mus.*, vol. iii, No. 4, 1906, p. 597, text-fig. 1.

[7] Raymond, *7th Rept. Vermont State Geol.*, 1910, p. 237, pl. xxxvi, figs. 7–9, and references.

[8] Clarke, *Lower Silur. Trilob. Minnesota*, 1894, p. 742, text-fig. 59.

The relations between *Encrinurus* and *Cybele* are much more marked in the case of the head-shield than of the pygidium. Particularly is this seen in the glabella of such forms as *Cybele brevicauda* Ang. in which the lateral lobation and shape of the frontal lobe recall *E. sexcostatus* and *E. fallax*. We may also draw attention to the resemblance of its head-shield to that of *Encrinurella insangensis* in these respects. The frontal marginal fringe of large tubercles which is present in *E. multisegmentatus* and *E. seebachi* is also developed in much the same way in *C. brevicauda* Ang. as figured by Schmidt,[1] and also in *C. kutorgae* Schm., another closely allied species.[2] But the course of the facial sutures in the two genera is quite different, and the resemblance of the glabella and frontal fringe can only be regarded as an instance of parallel development or homoeomorphy.

From the preceding examination of the characteristics of the various species of the genus *Cybele*, we see that there are four well-defined groups or sub-genera recognizable and that their characters are so distinct as to merit individual designations. One of the groups has already received the distinctive name *Cybeloides* as above described, and we may proceed to affix designations to the others.

(1) The first group is that of *C. bellatula* and *C. panderi* having incomplete axial rings and five pairs of pleurae in the pygidium, but especially characterized by the peculiar features of the head-shield as given above. This group may receive the sub-generic name *Cybelina*.

(2) The second group comprises the genotype *C. verrucosa* Dalm. as well as *C. wörthi* Elchw. and several other species. It has only four pleurae in the pygidium, and the features of the head-shield have been described above. This group is *Cybele* sens. str.

(3) The third group which is typified by *C. rex* Nieszk. is sufficiently distinct in its cephalic characters from the two foregoing groups to deserve a special sub-generic title, and *Cybellela* is suggested.

(4) The fourth group of European species comprising *C. loveni* and its varieties and *C. rugosa* Portl. must be regarded as belonging to the American group *Cybeloides*, which is at any rate of sub-generic rank.

The first three subgenera correspond very closely with the three groups established by Schmidt amongst which he distributed the Baltic species, the fourth sub-genus here given being recognized by him as constituting an independent group.

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[1] Schmidt, op. cit., p. 219, t. xi, fig. 23, t. xiv, figs. 7–10, t. xv, figs. 15–17; Warburg, op. cit., 1925, p. 337, pl. xi, fig. 38.

[2] Schmidt, op. cit., p. 217.

(5) The genus *Dindymene* Corda, 1847.

The genus *Dindymene* is very compact, and the species do not show such important and considerable differences in structure as have been above noted in *Cybele*, though Lindström[1] has expressed the opinion that *D. fred. augusti* Corda, the type of the genus, is so distinct from the other Bohemian species *D. haidingeri* Barr. that they ought to be put into separate genera. But Barrande only enumerated trivial points of difference, and both species occur on the same stratigraphical horizon in Bohemia.[2] The absence of facial sutures in this genus has been considered of primary importance, but in one new Swedish species *D. pulchra* founded by Olin[3] facial sutures are clearly shown to exist, cutting off narrow free cheeks, though the other Swedish species[4] seem to have none, and all are devoid of eyes. According to Wiman[5] the genus has not been found in the East Baltic, and in Sweden it is limited to the Trinucleus Shales. The genus does not appear to have been recorded in America, or indeed outside Europe, and is not mentioned at all by Raymond in Eastman Zittel's *Text Book of Palaeontology*, 2nd edition, 1913.

There are only two species of *Dindymene* known in the British Isles, and they are *D. hughesiae* Reynolds[6] from Yorkshire and *D. cordai* Nich. and Eth.[7] from Girvan, both of which have been described in some detail and compared with the Bohemian members of the genus.

It is difficult to see any conspicuous points of resemblance in the head-shield to that of other members of the family, but the pygidium has some features in common with *Cybele*. The absence of eyes and the consequent loss of facial sutures seems to be a secondary feature of an adaptive nature, and not to bear any phylogenetic interpretation.

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[1] Lindström, *Kongl. Svensk. Vet-Akad. Handl.*, vol. xxxiv, No. 8, 1901, p. 11.

[2] Reed, "Lower Palaeoz. Trilob. Girvan," Suppl. 1914, p. 45.

[3] Olin, *Medd. Lunds, Geol. Faltklubb*, ser. B, No. 1, 1906, p. 50, t. 1, figs. 21, 21*c*.

[4] Olin, op. cit., pp. 50–2. Linnarsson, op. cit., 1869, p. 64, t. i, figs. 15–17.

[5] Wiman, *Bull. Geol. Instit. Upsala*, vol. viii, 1907, p. 150.

[6] Reynolds, GEOL. MAG., Dec. IV, Vol. I, 1894, p. 108, pl. iv, figs. 1, 5. Reed, ibid., p. 246, pl. vi, figs. 4, 5.

[7] Etheridge and Nicholson, *Mon. Silur. Foss. Girvan*, fasc. 1, 1878, p. 115, pl. viii, fig. 8, and p. 116, figs. 5*a*, *b*. Reed, "Lower Palaeoz. Foss. Girvan": *Palaeont. Soc.*, 1906, pt. iii, p. 132, pl. xvii, figs. 9–11. Ibid., Suppl. 1914, p. 44, pl. vii, figs. 8, 9.

Geological Studies in the Dublin District: II. The Problem of Carrickgollogan.

By F. Smithson, B.Sc., F.G.S.

In the first part of this paper an account has been given of the heavy minerals of the northern part of the Leinster Granite and of the contiguous rocks in the Ballycorus district.

In the present part the structure of the district will be discussed with special reference to the structure of Carrickgollogan (Fig. 1).

On the south-east margin of the Leinster Granite in the county of Dublin there is a belt of slates, which, near the granite, have been converted into mica-schists. Although no fossils are found in this belt of rocks it has been usual to assign them to the Ordovician.[1] In the middle of this belt there is, around Carrickgollogan, a small patch of slates and quartzite, which are similar to the slates and quartzite of the Bray Series, commonly held to be Cambrian. This small area has attracted much attention and various have been the hypotheses put forward to explain its structure. These views are best understood from Fig. 2, which illustrates a series of hypothetical sections drawn through Carrickgollogan from N.W. to S.E.

Du Noyer, who surveyed the district in 1860, inserted a note on his manuscript map to the effect that there was no evidence for the Cambrian age of the quartzite of Carrickgollogan, which he remarks rests in a hollow on the " Lower Silurians ".

Blake (1888) considered the rocks of Carrickgollogan to be Pre-Cambrian, and included them in his Monian system. He remarked that these rocks " come in defiance of stratigraphy " and that if they are disposed according to the observed banding they must be faulted on all sides. It may be mentioned here that Jukes (*Mem. to Sheets* 121 *and* 130, pp. 14–15) held that the main Cambrian area of Wicklow was divided from the Ordovician (or, as he termed it, Silurian) by a N.E.–S.W. fault.

Sollas (1893–4) accepted the usual view that the Ordovician strata rested on the supposed Cambrian. He considered that the fact that the Cambrian rocks were never seen in junction with the granite could be explained by supposing that " the granite is of the nature of a laccolite, with the Ordovician for cover and the Cambrian for a floor ". This interpretation seems to imply that Carrickgollogan must have been an island in the sea in which the Ordovician sediments were laid down, but there is no evidence of anything approaching a littoral deposit, and the general dip of the Ordovician strata at about 30 degrees away from the granite hardly conforms with this hypothesis. Moreover, the comparatively uniform width of the belt of Ordovician rocks between the granite and the Cambrian rocks is not in keeping with the view that the Ordovician is the cover of a granite laccolith, which rests on a Cambrian floor. Such a feature would be much more likely to arise if the Ordovician strata lay above the granite but below the so-called Cambrian.

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[1] There are no very strong grounds for doing so, but evidence of contemporaneous vulcanicity suggests that they may be of the same age as the andesitic lavas and tuffs of Lambay Island and Portraine (Co. Dublin), which are definitely known to be Ordovician.

McHenry (*Mem. to Sheet* 112, pp. 7–8) wished to place all the sediments of this area in the Silurian (" Upper Silurian ") and considered that the rocks of Bray and Carrickgollogan rested conformably on the slates now mapped as Ordovician. A criticism of these views is given in the memoir, where Lamplugh remarks that " they would undoubtedly remove certain difficulties in explaining the relation of the so-called Cambrian and Silurian rocks and would simplify our ideas of the general structure of the Older Palaeozoic rocks of south-eastern Ireland ". But he adds that " caution is desirable before accepting this revolutionary change in the reading of the district, though the necessity of further investigation may be readily admitted ". McHenry recognized that in places there was an apparent unconformity between the supposed Ordovician and Cambrian rocks, and attributed it to " the great differential movements in which the whole of the Older Palaeozoic rocks have undoubtedly been implicated in this district ".

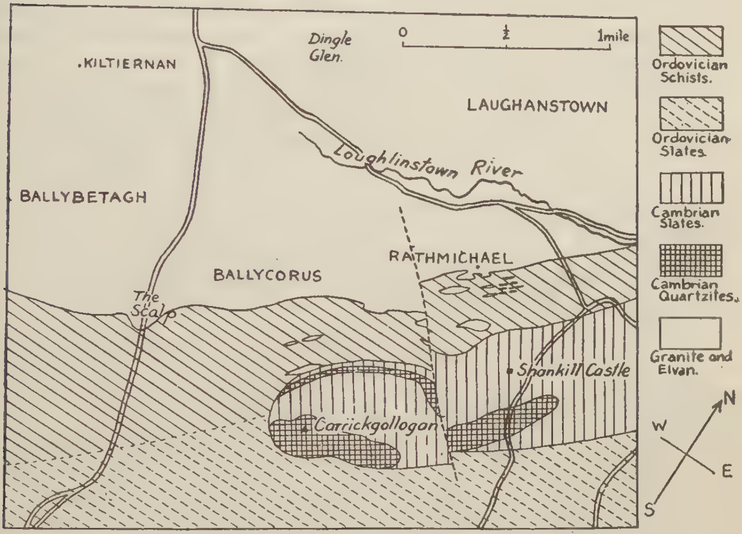

FIG. 1.—Map of the district around Ballycorus.

Cole (1921) accepted the Cambrian age of the Carrickgollogan rocks and also accepted Du Noyer and McHenry's view that they rest upon the slates which are mapped as Ordovician. He considered that the Cambrian rocks were divided from the Ordovician by a thrust plane. He suggested that the thrusting had taken place as part of the Caledonian earth-movements after the intrusion and solidification of the granite; that the whole of the Cambrian rocks of northern Wicklow have been "imported into the region by thrusting from the east"; and that "Carrickgollogan, though technically an inlier, should be regarded as an outlying 'klip'". Unfortunately Cole presented very little new field evidence, for he arrived at his conclusions in an attempt to reconcile the conflicting interpretations given by previous workers.

Certainly, Cole's hypothesis clears up many of the apparent contradictions and difficulties. It makes the junction between the Carrickgollogan mass and the Ordovician strata a faulted one as Blake demanded—the thrust plane being a more or less horizontal fault. It makes the Carrickgollogan mass rest upon the Ordovician strata, which is the order of superposition accepted by Du Noyer and McHenry, and it also takes into account the "great differential movement". But whilst it is easy to accept the view that Carrickgollogan is an outlying "klip" of Cambrian rock, with its base some five or six hundred feet above sea-level, the interpretation seems to require some modification when applied to the area south of Shankill Castle, where the base must be considerably lower than 200 feet.

In an attempt to afford some definite evidence of the structure of this problematic area the present writer has pursued research in three directions:—

(*a*) A comparison of the heavy mineral suite of the Carrickgollogan quartzite with that of some of the quartzites near Bray, which are usually accepted as Cambrian.

(*b*) An examination of the granites, aplites, elvans, schists, and quartzites for evidence of strain and crushing and observation of the intensity of these phenomena.

(*c*) An examination of the systems of jointings as possible indicators of earth-movement.

HEAVY MINERALS OF THE QUARTZITE.

The heavy minerals of the quartzite of Carrickgollogan have already been described in detail in the first part of this paper.

The crushing of twelve quartzites from the Carrickgollogan mass and five samples from the Great Sugar Loaf Mountain near Bray, show that colourless and purple zircon, leucoxene, tourmaline, rutile, and ilmenite are common to both areas and are present in similar proportions.

LOCAL VARIATIONS OF THE GRANITE.

The Leinster Granite is not a perfectly uniform intrusion. The proportion of biotite to muscovite varies considerably, whilst some parts are much coarser grained than others. Kinahan (1878) considered that there were two granites of two distinct ages "partly jumbled up together and hard to separate on account of the paucity of sections, also because some of the characters of the different rocks are so similar". But it seems more likely that the differences are due to a gradual differentiation of the magma and to the introduction of material from the overlying schists.

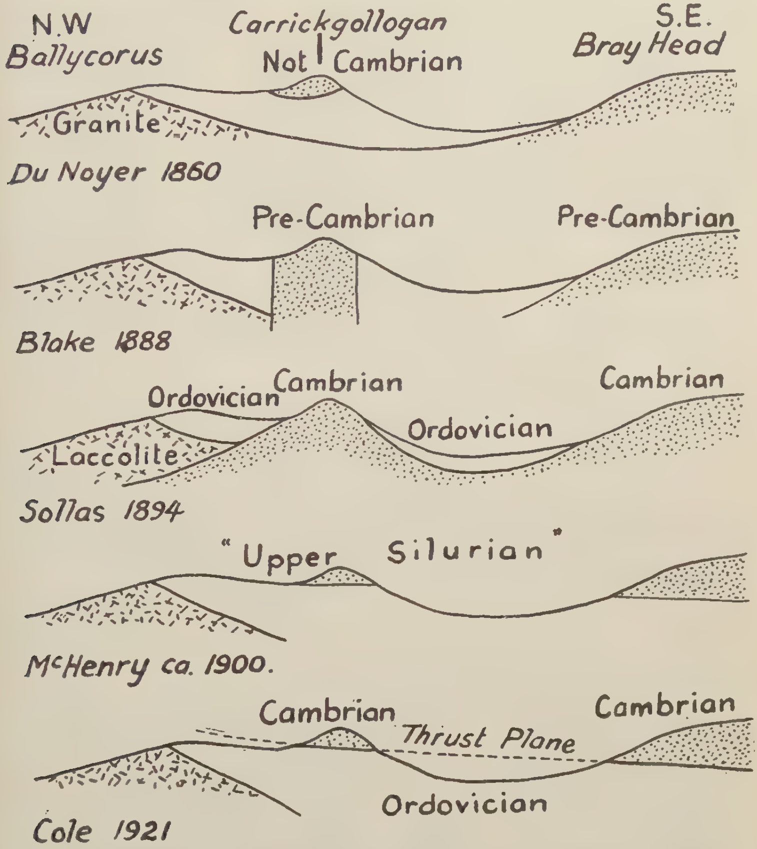

Fig. 2.—Diagramatic sections to illustrate various views upon the structure of Carrickgollogan.

The greatest textural differences, however, are due to compression after consolidation. When thin sections of the granite are rotated between crossed nicols the quartz usually shows strain shadows. Sometimes the shadows are slight, but at the Scalp and Ballycorus the phenomenon is very pronounced and clearly indicates that the rocks have been subjected to intense pressure. At places well removed from the margin the granite of the rock shows no outward signs of compression. At the Scalp and Ballycorus, however, the pressure has produced a structure already described by Sollas (1889) who, writing of the granite at the Scalp, remarked, "Gliding surfaces run in an undulating fashion through the rock, dividing it up into a number of more or less lenticular masses or phacoids which present in section the form of a double snake-like curve; the greater part of the phacoid usually consists of a larger or smaller crystal of felspar, the presence of which has in most cases determined its existence. . ." These gliding surfaces give a distinct "grain" to the rock. At Ballycorus granite of this type is exposed over a wide area, and it has been possible to make a large number of determinations of the direction of this "grain". In thin sections such a granite shows pronounced signs of strain. Frequently a patch of quartz is seen to consist of an assemblage of highly strained individuals, granular and crenulated at the margins. The muscovite plates are often severely distorted, but curvature of the plagioclase crystals is not common and never severe. In the Ballycorus granite the crushing is rather more intense than at the Scalp. Some of the felspars are broken and their parts displaced, whilst portions of the rock have acquired a granulated structure.

LOCAL VARIATIONS OF THE LEUCOCRATIC ROCKS.

Hitherto very little attention has been paid to the minor intrusions around the granite. A large number of thin sections have now been prepared, and the degree of crushing shown by the various intrusions has been found to afford the most striking confirmation of the views put forward by Cole concerning the structure of the area.

At the Scalp and Ballycorus the aplites show signs of compression to about the same extent as the granite. The aplites at Rathmichael show the same phenomena, but as the minor intrusions are traced to the south-east, the degree of alteration becomes greater. In those intrusions which adjoin or lie near the granite there are strain shadows in the quartz and orthoclase, whilst sometimes the plagioclase is slightly warped. Occasionally there are patches in the section where granulation has occurred. The garnets have been cracked and chloritization has frequently developed along the cracks. In one place the structure of the elvan resembles that of the phacoidal granite of the Scalp. But the largest of the Rathmichael intrusions, which is also the farthest from the granite, has suffered most severely from crushing. This rock consists of irregular grains of quartz and felspar embedded in a mylonitic groundmass. The large grains show signs of severe strain. In the case of one piece of orthoclase a rotation of 54 degrees was necessary to cause an extinction-shadow to move from one extremity to the other. The severe crushing seems to have paved the way for further alteration, for much pale green pinite has been developed in the matrix, probably from the felspar-crush. Pinite as an alteration product of felspar has been recorded from Ballycorus (Smyth, 1922). A very similar pinitized, mylonitic rock is exposed in a stream to the south in the township of Shankill.

The elvan intrusion lying about a furlong N.W. of Carrickgollogan is rather different in type from the Rathmichael intrusions. Though leucocratic in appearance it contains a little pale green chlorite with pleochroic haloes, which is evidently an alteration product of biotite. The heavy residue contains abundant garnet, some apatite, and a little zircon. The rock is rather coarse in texture. Curvature of the plagioclase is more noticeable here than elsewhere, but many of the plagioclase crystals, instead of bending have broken. In places the rock shows a structure which is best described as that of a breccia on a microscopic scale. In other places, however, the rock is reduced to a mylonite, in whose fine-grained groundmass larger fragments of the original grains survive.

THE ORDOVICIAN.

Reference has already been made to the fact that full gradation from schists to unmetamorphosed sediments is not seen in the Ballycorus district. On the south-east side of the Carrickgollogan mass the slates belonging to the Ordovician are unmetamorphosed, whilst immediately to the north-west of the Carrickgollogan mass there is an intrusion of elvan with biotite-schist exposed close at hand.

The schists near the granite are thrown into a series of comparatively gentle folds, but as the Cambrian rocks are approached the folding becomes more severe until within about a hundred yards of the Cambrian rocks they present a series of acute V-shaped folds.

THE CAMBRIAN.

In thin sections the quartzites of the main part of the Carrickgollogan mass are very similar to those of the Great Sugar Loaf, but the quartzites which outcrop to the north-west of Carrickgollogan offer a marked contrast.

In the normal Carrickgollogan type the appearance is similar to that of an ordinary sandstone. Where a ferruginous cement is present the outline of the grains is distinct. Where the grains are cemented by secondary silica, the cement is usually less clear than the original grain. But the structure is most plainly revealed between crossed nicols, when the fine-grained quartz mosaic of the cement shows up clearly around the grains and the different optical orientations of the various grains reveal their shapes distinctly. As Sollas observed (1892) sericite appears to have been developed between the grains in some of the quartzites. As a rule each grain is an optical unit with a smooth outline, but all the grains show more or less distinct strain-shadows when rotated between crossed nicols, whilst sometimes the outline appears somewhat crenulated. Frequently faint lines appear in the section, running in many directions and intersecting in a complex manner. High magnification shows that these lines are really planes of very minute gas bubbles.

But these signs of alteration are slight in comparison with those observed in thin sections of quartzites from the north-west area. Here the structure of the original sediment can usually be made out, but between crossed nicols the rock is seen to be almost entirely recrystallized to form a fine quartz mosaic. Where a grain has resisted recrystallization the outline is irregular and crenulated, but most of the grains have completely recrystallized. The grains of zircon have been cracked or shattered into small fragments. Chlorite is present, either in flakes disseminated through the rock or filling small cavities.

The facts given in the sections dealing with the igneous and metamorphic rocks may be summarized in the statement that the effects of dynamic metamorphism increase as we recede from the middle of the granite and approach the Cambrian rocks. When we pass over into the Cambrian area the increase of the dynamic metamorphism ends. It is the Cambrian rocks lying nearest the granite which have suffered most severely. The finer grained and more slaty rocks along the north-west margin of the Cambrian area have been much puckered and folded. Exposures of such rocks in situ are few, but numerous fragments can be obtained from the soil, especially where the ground has been trenched to form field boundaries. If the junction of the Cambrian and Ordovician strata is marked by a thrust-plane we should expect to find similar phenomena all round the Carrickgollogan mass, but unfortunately exposures are absent at the critical points. High on Carrickgollogan the quartzite is little altered, and even the original bedding can be observed as a faint banding. At lower altitudes this banding is not seen, whilst on the south-east slopes the rock is much disturbed and brecciation is common. The breccias consist of fragments of quartzite, vein-quartz, and slate, cemented together with a ferruginous cement. The presence of fragments of vein-quartz shows that before the brecciation took place the rock was already traversed by veins of quartz, whilst the presence of fragments of slate where no beds of slate are exposed close at hand suggests considerable movement. This evidence is confirmed by the fact that joint planes in the quartzite are frequently marked with gliding striae.

All available evidence thus goes to prove that dynamic metamorphism, intense folding, and similar phenomena come more into prominence as we approach the junction of the Cambrian and Ordovician rocks, and this is in agreement with the view that the two systems are divided by a thrust plane.

It may be asked, " At what period did this thrusting take place ? " Since the minor intrusions have been mylonized as a result of the movement, it is clear that it must have taken place after their intrusion, and since the elvan represents a late phase of intrusion the movement must have taken place considerably later than the intrusion of the granite. Thus the usual effects of contact metamorphism which are seen in the Ordovician rocks do not extend into the Cambrian region.

A very remarkable exposure of rock which affords valuable confirmation of these conclusions has been found by the present writer at the north-eastern extremity of the elvan intrusion which lies nearest to Carrickgollogan. Here is a large block which has the appearance of a jumbled mass of elvan and slaty rock. The rock is probably in situ, but that is a matter of small account since the elvan matches perfectly the mylonized elvan occurring in the intrusion. In thin section the rock shows signs of severe crushing, from which the elvan in particular has suffered. The fragments of sedimentary rock are seen to be of a rather fine-grained arenaceous type such as occurs in the Cambrian near by. It contains chlorite, which does not appear to be an alteration product of biotite, whilst there are no signs of the development of garnet or of tourmaline such as is seen in the Ordovician rocks around the minor intrusions. Thus, although previous mapping has placed the boundary of the Cambrian rocks some distance from this intrusion, here we seem to find Cambrian rock and elvan actually in the same slide.

JOINTING.

A full examination of the evidence of the jointing directions would involve too long a discussion for the present paper, and the nature of the evidence will be given only in outline.

The supposed Cambrian rocks, which extend westward from Bray, are shown on the Survey maps to be cut by numerous faults. Most have a direction approximately N.N.W.–S.S.E., whilst north of the Great Sugar Loaf a sinuous fault runs in a general E.–W. direction. An examination of the data collected by O'Reilly (1880–9) shows that the jointing of this region tends to follow the N.N.W.–S.S.E. fault system or to lie at right angles to it, and to a less extent to be determined by the sinuous E.–W. fault.

Passing to the Cambrian rocks around Carrickgollogan, we find a much more complex system of jointing,[1] the joints running in almost every direction. In all the exposures, however, jointing at about W.N.W.–E.S.E. is prominent, and it is significant that this is also the direction of gliding striae on Carrickgollogan and similar markings on the neighbouring schists, and lies at right angles to the direction of the " grain " in the granite at Ballycorus, and to the axis of the Leinster Granite. N.N.W.–S.S.E. jointings occur with fair frequence, but the jointing system shows no dominant direction.

On passing north-westward from Carrickgollogan and entering

[1] Observations by the writer.

the belt of Ordovician rocks a much simpler system of jointing is at once encountered.[1] The jointing is best seen in the minor intrusions of elvan which occur amongst the schists, but the schists show the same system with its dominant set of joints running approximately E.–W.

In the granite the E.–W. jointing is frequently important; but in many localities the dominant jointing is nearly N.W.–S.E. This latter set is very conspicuous at Dalkey and Killiney,[2] and in the district east of Dingle Glen.[1] The last-named locality lies in the line of an apparent fault at Rathmichael, and the two phenomena are probably connected.

The evidence of jointing thus offers certain support to the thrust-hypothesis put forward by Cole. A sudden change in the type of jointing occurs just at the line where the supposed thrust plane would come to the surface; and the extreme complexity of the jointing of the Carrickgollogan mass is just what might be expected in an overthrust mass, which, having possessed joints prior to the movement, acquired further joints during the thrusting and was, perhaps, later split along the lines of weakness of the underlying rocks.

That some of the joint planes both in the granite and in the quartzite are actually planes of differential movement is shown by the gliding striae upon them.

MAPPING.

The junction of the granite and the schist can be traced clearly over a great part of its length in the Ballycorus district. The granite surface and the schists dip E.S.E. or S.E. at an average angle of about 30 degrees, though in places the schists stand vertically or are thrown into over-folds.

At Rathmichael a small valley cuts across the ridge formed by the granite-schist junction. Here the rocks are concealed, but an examination of the line of junction on the high ground on either side of the valley shows that there is a displacement of about a furlong, as though the valley marked the position of a N.W.–S.E. fault with a down-throw of about 300 feet to the N.E. Such a fault was inserted by Du Noyer on his manuscript map, but has never appeared on any published map. Du Noyer did not continue the fault-line far to the S.E., but the line is marked by a steep slope and this feature extends into the Cambrian region, suggesting that the fault affects the Cambrian rocks also. Moreover, the continuation of this fault to the S.E. removes the difficulty that has already been pointed out, namely, that the quartzite south of Shankill Castle appears some two or three hundred feet lower than we should expect if we took into account the thrusting movement alone.

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[1] Observations by the writer.

[2] From observations by O'Reilly.

The boundary between the Cambrian and Ordovician rocks cannot be definitely traced, as exposures are lacking here as they are in Wicklow. It is this absence of exposures which has allowed so many divergent interpretations of the structure to remain undisproved; all seemed to agree equally well with the known facts.

CONCLUSIONS.

The evidence given in this paper confirms the hypothesis put forward by Cole to explain the structure of the region.

The quartzite of Carrickgollogan shows a close lithological similarity to the quartzite of the Great Sugar Loaf region, and so long as the Bray Series is assigned to the Cambrian we are justified in placing the rocks of Carrickgollogan in the same system.

The Carrickgollogan mass appears to rest upon the so-called Ordovician, thus hiding part of the metamorphic aureole. The schists and minor igneous intrusions lie on one side of it and slates on the other, the phyllites probably being concealed by the overthrust Cambrian mass. This interpretation of the structure is borne out by the evidence of dynamic metamorphism, and by the study of the jointing.

There is evidence to show that the over-thrusting was from E.S.E., and it is of interest that this must also have been the direction of the over-thrusting in the great N.W. Highland thrust. Indeed, Cole held that both the intrusion of the granite and the subsequent over-thrusting in Leinster were part of the great Caledonian orogenic movement.

The writer wishes to express his thanks to the Geological Survey of the Irish Free State for permission to examine the manuscript maps by Du Noyer.

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A Metamorphosed Nodular Shale previously described as a "Spotted" Metamorphic Rock.

By L. R. Wager, Sedgwick Museum, Cambridge.

In the Geological Magazine for 1895[1] and again in 1898[2] W. M. Hutchings gave a petrological description of a shale, metamorphosed by the Whin Sill of Teesdale, which showed three unusual features. Scattered irregularly through the hardened shale were large nodules about the size of a pea which Hutchings considered to be the results of the metamorphism, in fact to be unusually well-developed "spots". The second peculiarity was that both matrix and nodules contained considerable amounts of an isotropic material which was maintained to be the result of incomplete crystallization of a dense solution formed from the constituents of the shale during metamorphism. Finally, the detrital quartz grains of the shale were found to be extensively replaced by muscovite or more rarely other minerals. A re-examination has been made of the rock and also, by the courtesy of Professor G. Hickling, of Armstrong College, Newcastle-upon-Tyne, of certain of Hutchings's slices. In this note it is not intended to redescribe what has been ably described in Hutchings's papers, but as briefly as possible to make two corrections of Hutchings's conclusions.

The eight-foot bed of nodular shale occurs about 75 feet below the base of the Whin Sill dolerite at a steep bluff known as Falcon Clints, which overlooks the River Tees about a mile below Cauldron Snout. The bed was discovered by Professor E. J. Garwood, who supplied Hutchings with the material with which he worked. A re-examination of the exposure showed that nodules occurred in the Basal Carboniferous Conglomerate which were identical, when examined by the naked eye, with those in the immediately overlying nodular shale. Under the microscope the nodules of the conglomerate are seen to consist of concentrically arranged chlorite crystals with a variable amount of detrital quartz and are similar in many ways to the chlorite oolitic iron ores described by A. F. Hallimond[3] and others. In some cases a broken nodule has formed the centre for further concentric deposition of chlorite crystals. This is the sort of evidence which makes it certain that the nodules in the conglomerate were not formed by the metamorphism of the dolerite but were original constituents of the conglomerate. The nodules described by Hutchings in the shale above are variable, but on the whole show little resemblance to those in the conglomerate, and Hutchings was led to conclude that they "represent the drawing together and concentric deposition of a substance formed in the shale during contact-metamorphism". A series showing a complete and gradual transition between the nodules in the shale and those in the conglomerate has not been found, but there are sufficient intermediate stages to indicate that they are essentially similar, and hence that the nodules which Hutchings described are only metamorphosed nodules originally present in the shale. Probably there is a primary difference of chemical composition between the nodules in the conglomerate and the shale corresponding to a change from an essentially chloritic sediment to a more sericitic, and these differences are further increased by the metamorphism of the nodules in the shale and not those in the conglomerate. Rare nodules occur in the shale in which despite the metamorphism it can be seen that the detrital quartz was more abundant in the nodule than in the surrounding matrix. More frequently the nodules show less detrital quartz than the matrix and this was explained by Hutchings as the result of partial solution of the detrital quartz. No explanation based on metamorphism would be satisfactory for those nodules having more detrital quartz than the surrounding shale, and both cases are easily explained if the nodule is an original feature of the shale. The nodules cannot therefore be regarded as well-developed "spots", the result of metamorphism, but as nodules washed into or formed in the shale when it was being laid down, and long after much altered by the Whin Sill.

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[1] "An Interesting Contact Rock," Geological Magazine, 1895, p. 122.

[2] Geological Magazine, 1898, pp. 78–9.

[3] *Special Reports on Mineral Resources of Great Britain*, No. 29, 1925.

The isotropic areas in the material surrounding the nodules are difficult to make out because, like the sericite and newly formed quartz crystals imbedded in it, they are clouded with inclusions which under the $\frac{1}{12}$ in. objective usually show the shape and colour of rutile. The material so far as can be seen in ordinary slices is completely isotropic, but it has not all the same refractive index. Some is chlorite having a higher refractive index than the surrounding muscovite and giving a dark brown colour on roasting the slice at red heat. Other areas are less definite and have a refractive index well above balsam and about equal to or slightly less than the general refractive index of the sericitic aggregates. These areas are probably kaolin, as the one analysis of the rock made by Hutchings indicates that kaolin should be present, though he merely gives the analysis without comment. There is no material having a refractive index sufficiently low to make it possible to assume that it is a glass of the appropriate composition.[1]

The other interesting observation of Hutchings that the detrital quartz has been replaced by other minerals, generally muscovite, has been confirmed in all slices that have been cut of the nodular shale. The quartz itself has not been recrystallized, but the margins are replaced by muscovite flakes which project into the quartz grain. The process may go on until only a small core of quartz remains or till the whole is replaced by muscovite. This does not seem to be by any means a common occurrence in the metamorphism of shales ; but mention is made in the Edinburgh Survey Memoir [1] of detrital quartz grains which appear to have been attacked during metamorphism by a basic sill, and this may be a similar case. Near mineral veins the metasomatic replacement of quartz by sericite is not infrequently described. Hutchings made an analysis of the nodular shale, and though he did not describe any slice of the particular specimen which he analysed, it is interesting to calculate very roughly its probable mineralogical composition. Hutchings describes slices in which he found albite, but this has not been confirmed, and it will be sufficient to consider that all the alkalies are present as a sodium-potassium mica and all the iron as amesite.

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[1] C. E. Tilley, "Density, refractivity, and composition relations of some natural glasses," *Min. Mag.*, vol. xix, 1922, p. 275.

ANALYSIS OF THE NODULAR SHALE, FALCON CLINTS, TEESDALE. ANALYSIS BY W. M. HUTCHINGS.

	%
SiO_2	60·15
Al_2O_3	25·43
Fe_2O_3	3·95[2]
MgO	trace
CaO	0·45
Na_2O	2·01
K_2O	1·25
H_2O	7·20
	100·44

Calculated mineralogical composition.

Sericite	36·5
Kaolin	22·4
Amesite	8·5
SiO_2	31·5
Other minerals	1·1
	100·0

Despite the roughness of the calculation of the mineralogical composition it is sufficient to show that kaolin should be an important constituent. Were any of the soda present as albite this would increase the quantity of kaolin. Minutely crystalline kaolin probably forms the main bulk of the isotropic material described by Hutchings. As the rock contains an excess of alumina all that is necessary to produce a reaction between the detrital quartz and the kaolin to give sericite is that alkalies should be introduced. The conditions differ from those producing adinolization in that the shale affected is not near the contact but 75 feet below and the intrusion is a quartz-dolerite and not an albite-dolerite such as might be expectd to yield alkaline solutions. In all well-exposed outcrops of the Whin Sill that have been examined in Teesdale and Weardale an early sweeping joint system has allowed the attack of the dolerite along the joints by late magmatic waters and the sides of the joints are altered sometimes for as much as two inches to a variable rock consisting essentially of chlorite, quartz, and calcite. This alteration probably produced alkaline carbonate solutions and it is suggested that these were the solutions which, with the kaolin of the shale, produced the replacement of the detrital quartz by muscovite.

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[1] " Neighbourhood of Edinburgh," *Mem. Geol. Surv.*, 1910, p. 314.
[2] A part is present as ferrous oxide—hence excess in the analysis.

I wish to thank Dr. C. E. Tilley for help and for reading through this note when it was in manuscript.

REVIEWS.

PHOTOTOPOGRAPHY: A PRACTICAL MANUAL OF PHOTOGRAPHIC SURVEYING METHODS. By A. L. HIGGINS. pp. xv + 130, 9 plates, 43 figs. Cambridge University Press, 1926. 6*s*.

GEOLOGICAL survey is inseparably connected with topographical survey, and consequently this work will prove of interest to many geologists. The photographic method of constructing maps has been much neglected by English surveyors, though it has been of great service in Canada, and the only book in English on the subject has been long out of print. We have in the present work a very clear outline of the principles, and a concise account of the methods employed in the field and in the office, with directions for practical exercises. This is followed by a short account of the principles, main constructional features, and mode of use of some of the modern apparatus which has been used for stereophotographic surveys, but it is probable that few geologists will ever use these instruments, which in their latest forms are most intricate in their construction and of fabulous price. It is possible, however, that in the future the stereo-methods will come into more general use, especially in conjunction with photographs taken from the air.

There can be little doubt that phototopographic methods offer advantages to the geological surveyor in that they reduce the time spent on topographical work in the field even though the office work may be increased. At the same time the photographs may often provide the material for a large generalized survey of a wide area and also enable a very detailed map to be made of a limited region of special interest. On the other hand, it is impossible to construct a topographical map in the field and then to insert the geological information upon it using this method, but the photographs could often be developed and the geological data marked upon prints. This book should be of use to all those who are interested in map making, and merits the attention of geologists who have to construct new maps or revise old ones in the course of their work.

H. HAMSHAW THOMAS.

THE GEOLOGY OF THE COUNTRY AROUND WREXHAM. Explanation of Sheet 121. Part I. By C. B. WEDD, B. SMITH, and L. J. WILLS. Mem. Geol. Surv., 1927. 4*s*. 6*d*.

A WARM welcome has long been ready for this Memoir, although its publication has been considerably delayed. The country described is popular alike as a training-ground for geological students and as a resort for tourists, for it includes some of the most charming of Welsh scenery. Being essentially a description of the area of Sheet 121, the memoir takes its name—the Wrexham Memoir—from the chief town of the district. But Part I may well be regarded as an account of the geology of the country around Llangollen, for (except for the general discussion of the tectonics of the whole area) it is concerned in detail only with the Palaeozoic rocks lying below the base of the Lower Coal Measures and cropping out over the western two-thirds of the area. To have included the description of the Coal Measures, Trias, and Glacial Drift in a single publication would obviously have increased its size unduly; moreover, the separate Parts I and II will probably appeal to different types of inquirers.

In the present volume, therefore, we find successive chapters dealing with the Ordovician (Caradocian and Ashgillian), Valentian, Salopian, Carboniferous (a general account, including the Coal Measures), Carboniferous Limestone and Cefn-y-fedw Sandstone ("Millstone Grit"). Such a vast amount of labour has obviously been devoted to the investigation of the area and the writing of the Memoir that in a brief review it is possible only to indicate the scope of the work and incidentally to congratulate the officers concerned. Probably the most difficult, and certainly the most interesting, chapter of the Memoir is the opening one (if we exclude the introduction) on Tectonics. This chapter includes a conspectus of subsequent detailed descriptions, and an exposition of the authors' now well-known thesis on the spiral earth-movements in North Wales which resulted from torsional stress and strain. Like the country itself, this chapter is fascinating, but not easy to understand; from the involved account we gather the impression that the authors found it far from easy to express their meaning. We may state briefly (but with the usual imperfections of brevity) that the post-Carboniferous movements are believed to have been induced by long-continued pressure from the south against the Archaean barrier of Anglesey, at that time elongated north-eastwards. Relief was possible towards the north-east; hence arose the tendency to tangential movement externally and to clockwise adjustments with relatively backward torsional movement in spiral eddies in the inner part of the area. Arcuate faulting, tear-faulting, and, in places, overthrusting, yield evidence of the adjustments, local and regional, varying with the relative rigidity and position of the rock-masses involved. For the entrancing discussion of the tightening-up of the inner parts of the torsional eddies under contraction, and the movements of the secondary "hubs" adumbrated by the authors, the reader must be referred to the Memoir itself; every sentence in the latter part of chapter ii is indeed full of suggestion. The wisdom of making reference to the Anglesey massif at this stage of the discussion is questionable, because little is known of the tectonics of the extensive region (including the area of Ordovician rocks reinforced with igneous material) between this massif and the district under consideration.

In reading critically the detailed account of the fossil contents and distribution of the various divisions of the older Palaeozoic rocks, we should recall the fact that the mapping was completed fourteen years ago. While the faunas and relationships of the Valentian, Wenlock, and Ludlow rocks are now known to require revision and more thorough investigation in many parts of the area, the results achieved in 1913 undoubtedly marked a very great advance on earlier work. Further, it should be stated to the authors' credit that such detailed re-investigation as has been accomplished in recent years has served, not to question, but to substantiate their views of the tectonic history of the region.

Work on the zonal subdivision of the Carboniferous Limestone has resulted in only two horizons, D_1 and D_2, being determined with certainty. (Here we are tempted to ask if it may be possible to represent zonal subdivisions of these and older formations on the 1 in. map.) The Cefn-y-fedw Sandstone and its accompanying deposits are also fully discussed, but evidently no categorical statement as to exact stratigraphical position is yet possible.

This Memoir and the accompanying map will doubtless be "read" with interest not only by stratigraphers, but by students of tectonics both at home and abroad, for spiral movements have long attracted geologists, among them the illustrious Lapworth and Suess. In following these great intellectual flights, our foreign friends may in passing stumble over a small obstacle like "greywacké", a term mentioned but not defined in the text. In view of the extremely variable denotation of this gallicized-anglicized German word, might we not expunge it from our vocabulary?

P. G. H. B.

THE PRE-QUATERNARY SEDIMENTARY ROCKS OF SWEDEN. By ASSAR HADDING. Lunds Geologisk-mineralogiska Institution, No. 32, 1926.

AFTER giving a general account of the distribution of the various pre-Cambrian, Cambro-Silurian, Triassic, Jurassic, and Cretaceous sedimentary rocks of Sweden, the author describes in detail the different rock-types. His descriptions include useful information on sizing, rock and mineral constituents and fossil-remains. The heavy detrital assemblages and the authigenic minerals (e.g. phosphates and glauconite) also receive attention. Well-known rocks such as sparagmite and *Ceratopyge*-limestone naturally find a place in this comprehensive catalogue.

Part II of the monograph consists of a more detailed account of the Palaeozoic and Mesozoic conglomerates of Sweden. Some selected examples are described fully from the point of view of their petrographical characters, stratigraphical occurrence, and mode of formation. Thus the author is led to a genetic classification and grouping of the Swedish conglomerates, and finally to a discussion of their significance in relation to earth-movements. The obvious value of this publication suggests that it would be of great advantage if similar British sedimentary rocks were described in the same detail.

P. G. H. B.

THE GEOLOGY OF THE SOUTHERN PART OF THE SOUTH STAFFORDSHIRE COALFIELD (SOUTH OF THE BENTLEY FAULTS). By T. H. WHITEHEAD and T. EASTWOOD, with contributions by T. ROBERTSON. (Memoirs of the Geological Survey of England and Wales.) 218 pp., 13 plates, 5 text-figures. Price 6*s.* 6*d.* net.

THIS memoir covers the ground of parts of four sheets (167, 168, 153, and 154) of the New Series one-inch map. After a short chapter on the pre-Carboniferous rocks, there follows a detailed description of the Middle (Productive) Measures. At the time when J. B. Jukes wrote his famous original memoir on this Coalfield, long since out of print, this district was one of the most prosperous in the country, chiefly because of the association of the Ten Yard or Thick Coal and the then rich ironstones mined in association with it. Since that time much new ground has been mined, and the surface has become smothered by innumerable tip-mounds of waste and slag from the mines and blast furnaces. As a consequence, outcrops have been obscured, but some compensation is afforded by the largely increased data now available from mining plans. In this part of the book we get a particularly valuable and detailed, yet concise, description of the geological and mining facts.

It is significant that about twice as much space is devoted to the Upper Coal Measures, which are practically barren of workable coals, as is given to the Middle (Productive) Measures. And this is justified. For whereas the visible coalfield, where the Productive Measures outcrop, is now nearly worked out, the concealed coalfield along its borders, already partly explored, is largely for the future, and a detailed knowledge of the thicknesses and inter-relations of all the beds from the Etruria or Old Hill Marls to the Trias, is of supreme economic value.

The classification of these red beds below the Trias adopted by the Survey is admittedly tentative. We should realize the great difficulties in accurately mapping deposits practically destitute of fossils and constantly varying in lithology because of their accumulation on a varied land surface subject to continual movement. The chapters dealing with these difficult rocks are ably and clearly written, and full acknowledgment is given to the work of others in the same ground.

A brief account of the igneous rocks and mineral deposits and materials of industrial value comes at the end. Although this latter is too condensed to be of much practical value, there are numerous references to the literature dealing more fully with the same subject. The illustrations include very few text-figures, but there are thirteen excellent plates, six of which give vertical sections of the Coal Measures. W. S. B.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

"Dartmoor Detritals." A contribution to the Study of Provenance. By A. Brammall, Ph.D., M.Sc., D.I.C., F.G.S.

There is abundant evidence to suggest that the granites first uncovered on Dartmoor resembled those now exposed there. Hence, the present-day Dartmoor detritals probably resemble those dispersed from the granite outcrop since a remote post-Carboniferous epoch still to be determined. This determination would imply the recognition in post-Carboniferous sediments of true Dartmoor minerals in matrix derived from other sources, e.g. the Cornish granites and their aureoles.

There is reason to believe that each of these granites yields an alluvial mineral assemblage which is distinctive. This paper describes the Dartmoor assemblage, of which the most characteristic features are:—

(1) The association of manganiferous garnet, titaniferous biotite, zoned zircon, monazite, and ilmenite, with tourmaline, cassiterite, brookite, and anatase.

(2) Ilmenite in excess of magnetite; the rarity of sphene and rutile.

(3) The rarity of andalusite, topaz, and fluorite, and also of primary muscovite except in alluvials from the south-west part of the Moor.

Exclusive of felspars, quartz, and micas, the assemblage comprises the following species—arranged in order of average relative abundance:—

(1) Tourmaline, zircon, apatite, ilmenite. (2) Garnet, muscovite, monazite, cordierite (altered). (3) Anatase, brookite, magnetite, cassiterite, specularite. (4) Sphene, pyrite, amphibole, fluorite, rutile. (5) Spinel, topaz. (6) Andalusite. (7) Sillimanite, corundum, molybdenite. (8) Arsenopyrite, pyroxene, manganous oxides. (9) Barytes, autunite, torbernite—rare, and very local. (10) Gold—extremely rare.

The mere occurrence of a species, e.g. zoned zircon, is itself of little evidential value. The value rises only by virtue of (*a*) associations, (*b*) relative abundance, (*c*) specific identity, and (*d*) characteristics of inclusions. The ultimate value still rests on "coincidences", and may establish nothing more than a probability, which, to carry conviction, must be supported by numerous coincidences.

"Eocene and Pliocene Outliers between Chipstead and Headley, Surrey." By A. W. Groves, M.Sc., D.I.C.

A description is given of a Tertiary outlier, previously considered to be largely Clay with Flints, resting on the Upper Chalk of the North Downs. It is dissected by a number of dry valleys in the Chalk. With the exception of the southern boundary, which is very obscure, the limits have been mapped on the 6 in. scale. It consists of Thanet Sand and Lenham Beds, and, in addition, there are probably some remnants of Woolwich and Reading Beds. Some Eocene pebbles may indicate the former existence of Blackheath Beds. The deposits lie on a very uneven surface resulting from post-Thanetian solution of the Chalk. At the base of the Thanet Sand is a solution product which has been called Grey Clay with Flints, containing black-coated Flints. Other solution phenomena are described.

The mapping and sampling show the existence of a larger area of Pliocene than has previously been recognized. The petrography of the beds is described, and, in the Lenham Beds, evidence is given to show that the Dartmoor granite supplied some part of the material.

The following paper was taken as read :—

"The Petrology of the Spilsby Sandstone." By F. T. Ingham, B.Sc., A.R.C.S., A.I.C., F.G.S.

CORRESPONDENCE.

GEOLOGICAL SURVEY OF UGANDA

Sir,—An unfortunate error has crept into the Annual Report of the Geological Survey of Uganda for the year 1926, whereby the reader is informed that Mr. A. D. Combe, of this Survey, is of opinion that there is a continuous succession through the Transvaal System into the Waterberg System in the Cape Province of South Africa. May I be permitted to make use of your Journal to correct this, please ? Perhaps those of your readers who have copies of the report will kindly turn up page 32, delete line 34, and delete all of line 35 except the last word and the comma in front of it and rewrite so as to read :—

"Mr. Combe suggests that in the Katanga Province there may be a continuous conformable succession through the equivalents of the Transvaal and Waterberg Systems without an unconformity, similar to the grand conformable succession, in parts of the Cape Province through the Cape and Karroo Systems."

William C. Simmons.